Boston Society of Natural History.

GUIDES FOR SCIENCE-TEACHING.

No. VII.

WORMS AND CRUSTACEA.

BY ALPHEUS HYATT.

BOSTON:
D. C. HEATH & COMPANY.
1889.

WORMS AND CRUSTACEA.

THE space given to the description of the Lobster will, it is hoped, incite teachers to occupy more time in teaching some one common animal, and thus cultivating habits of close observation. How much pupils learn is of little importance; how they learn, everything, in the early years of training. It is not the amount of knowledge gained; it is the habit of persevering in seeing and thinking over and over again the same things until the mind can arrange and properly assimilate them, which makes a lesson in observation valuable.

This pamphlet could not have been published but for the assistance of Miss J. M. Arms, who prepared the text and most of the drawings, and some other person unknown to me, who has indulgently considered it of sufficient importance to teachers to be willing to defray the expenses of drawing the plates.

I also desire to acknowledge my indebtedness to the knowledge and critical ability of Mr. B. H. Van Vleck, Assistant in the Museum.

The plates were drawn by Miss Katherine Peirson of Salem, with accuracy and success, though the method of printing does not do justice to the fineness of the work.

Woodcuts, Nos. 19, 22, 23, 24, 27, 30, 36, are borrowed from Messrs. D. Appleton & Co. of New York, publishers of Morse's admirable little work, "First Book in Zoölogy."

Woodcuts, Nos. 20, 21, 28, 29, from George S. Bates of Salem, publisher of Emnerton's very convenient and accurately illustrated work, "Life on the Seashore."

The adult and young of Lenea branchialis, Fig. 40, are from original drawings by Mr. B. H. Van Vleck.

The courtesy and kindness of these authors and publishers have enabled us to illustrate this pamphlet very fully with figures of our own common animals.

We desire also to thank Mr. E. G. Blackford of New York, for the supplies of crabs, etc., furnished for this and other lessons of the course.

ALPHEUS HYATT,

Curator.

Boston Society of Natural History.

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WORMS.

The specimens which are needed for the lessons upon worms are the common earthworm, and the Nereis.*

To obtain the most satisfactory results with the earthworm, living specimens should be placed in a deep soup dish filled with fresh water. Abundant moisture is necessary to these worms; indeed, they cannot breathe freely unless their skin is damp, so that this treatment is not as cruel as it seems. The pupils should be led to observe that the body is long, cylindrical, and divided into rings or segments. The number of segments cannot be easily ascertained in the living animal, but in prepared or alcoholic specimens from one to two hundred may be counted, the number varying with the size of the worm. The deeper constrictions which form the rings are supplemented, in this creature, by shallower folds, or false constrictions, encircling the body, and dividing the surface of each true ring into two parts. These are mere skin folds, and, therefore, in counting the number of rings, it must be borne in mind that the true rings are only half as numerous as

* The common name for the Nereis is the "sea-centipede," but it is misleading, as the structure of the worm is very different from that of the well known land animal, Centipede, of the class of Myriapoda.

the apparent number of rings. The scholars should next observe that this segmented body is divided into three parts. The anterior portion (Fig. 1, *l* 1) tapers to a blunt point, and has the largest rings. The thickened middle portion (Fig. 1, *n*) is known as the "clitellum" or "saddle." The posterior part (Fig. 1, *l* 2) consists of segments of nearly uniform size, excepting a few at its extreme end, which are broader and flatter (Fig. 1, *w*).

A thin, tough cuticle composed of the peculiar substance, chitine, similar in appearance to horn, covers the whole body. This may be easily removed from alcoholic specimens which have lain in water two or three hours.

The brownish-red color of the exposed back of the worm, and the paler hue of the belly, should be observed, together with the beautiful iridescence of the cuticle. This iridescence is due to the breaking up of the rays of light by reflection from the many fine ridges running parallel to each other, and which may be observed by putting a piece of the cuticle under the microscope. These are really minute folds of the transparent, outer skin, and can be made to flatten out and disappear by stretching the specimen. The iridescence, at the same time, vanishes, proving that the brilliant play of colors is wholly due to the mechanical, file-like structure of the surface upon which the light falls.

The intestine can be seen as a dark streak in the interior, extending the whole length of the body, and opening through the last segment. Lying above the intestine is the blood-vessel, known as the pseudhaemal

vessel (Fig. 1, *dv*). This runs along the middle of the back above the intestine, like a very narrow red thread. It becomes apparent only during the pulsations when the tube is gorged with red fluid. This is regarded by most authors as distinct from the white blood which is found circulating in the cavities of the body, but not inclosed in special vessels. The vessels are, however, similar to the circulatory vessels of other animals in position and function, and can be properly spoken of as the circulatory system.* The pupils will observe that the first segment of the body is pointed, forming a sort of upper lip for the mouth which is immediately below. This mouth leads into a pouch, which is sometimes turned out, and becomes what is called a proboscis, for the purpose of taking food.

If the worm is turned upon its side, or closely observed from above on a white plate, short hairs, or setæ, as they are called, will be seen projecting from the surface (Figs. 1, 2, *s*). Place the animal upon moist earth, and watch it closely; it will then be seen that these setæ are used, upon such soft or uneven surfaces, to aid in the act of crawling; but if the earthworm be placed upon a pane of glass, or in a smooth dish, it will be found that, in spite of their number, the setæ are not suitable for moving the worm upon such hard and smooth surfaces.

* The white fluid of the visceral cavity is generally considered as the nutritive fluid, and as comparable in its structure to the blood of the Crustacea, which circulates in a circuit comprising vessels opening into the visceral cavity and the cavity itself. The worms, therefore, have two fluids to perform the two main functions of the blood in place of one combining both these offices, as in other animals.

When partially-dried or alcoholic specimens are examined with a lens, two double rows of these short hairs are observed on either side. One of the rows is seen just where the dark red color of the back fades into the lighter tint of the ventral surface, while the other is nearer the median line. Every segment, excepting the first, second, third, fourth, and last, has four pairs of these setæ. They are unjointed, and, as a rule, project forwards, so that when the worm is drawn gently through the fingers from the head to the tail, the resistance offered by the stiff hairs is very sensibly felt.*

The setæ extend a short distance into the interior of the body; and here there are muscles which move them forwards and backwards, like a double set of short crutches, when the animal crawls.

If the ninth, tenth, and eleventh segments of an alcoholic specimen are examined, they are seen to be much larger than the other anterior rings, and to have glandular swellings on their ventral surfaces. Four openings may also be observed between the ninth and tenth, and tenth and eleventh segments; these are in a line with the outer row of setæ, and are the four apertures of the seminal receptacles. On the fourteenth ring, just outside the inner row of setæ, are the two minute openings of the oviducts; and on the fifteenth segment the large, slit-like apertures of the seminal ducts may be observed. The earthworm is, therefore, an hermaphrodite, though self-impregnation

* This is contrary to Huxley, who states that the resistance is felt when the worm is drawn in the opposite direction, or from the tail to the head. After the death of the worm, the setæ may become fixed either way, being directed forwards in some parts of the body, and backwards in others; though, in the specimens examined, by far the greater number projected forwards.

does not occur. In the months of July and August pairing takes place, when each worm fertilizes the eggs of the other.

Along the middle of the back a row of pores may be detected by close examination, one in each segment, with some few exceptions, which lead into the body cavity.

In the earthworm there are no specialized breathing-organs, but aeration of the blood is effected through the whole skin. The sense-organs are also wanting, though the animal is susceptible to light-impressions, as may be easily proved. A few worms may be kept in a pot of damp earth, and when the room is dark they will come to the surface; but let direct rays of light fall upon them, and they will hastily retreat. According to Hoffmeister, these light-impressions are only received by the first two rings.

If a cross section of the body of the worm is made by the teacher, the relative position of the internal organs may be seen. Fig. 2 represents such a section.

Beneath the thin, outer cuticle (Fig. 2, *o*) there lies a thicker, transparent, and cellular layer known as the hypodermis (*hy*). Internal to this layer are bands of circular muscles, which extend continuously around the body of the worm (*q* 1). These bands are underlaid by five thicker bands of longitudinal muscles, which run the length of the body (*q* 2). Muscular septa extend inwards to the intestine, dividing the body cavity into separate chambers for every segment, except a few in the anterior part (*q* 3).

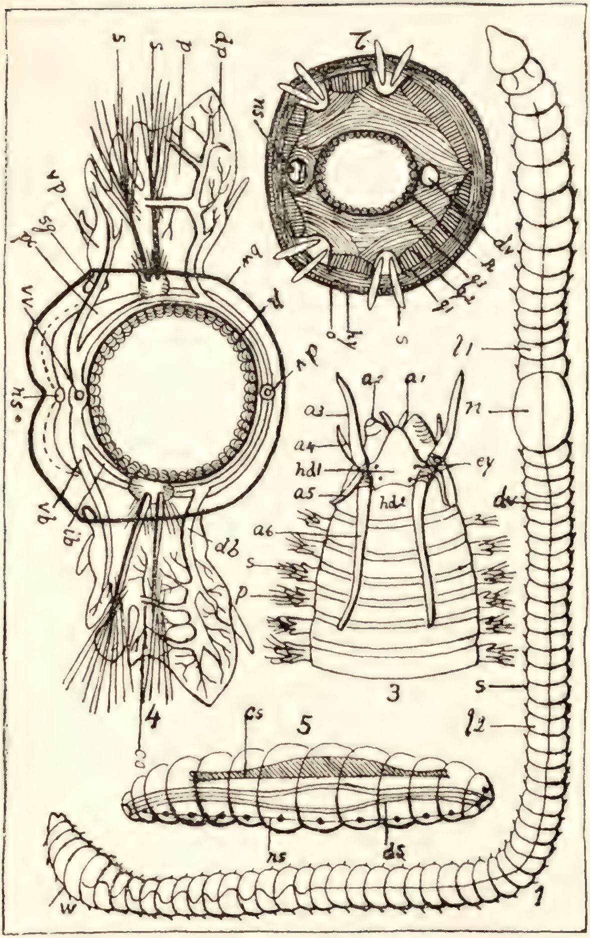
s is one of the eight setæ which are developed in sacs, and pass outward. Above the intestine (*r*) lies the pseudhaemal vessel already described (*dv*), and below it the nerve cord (*ns*), which runs along the floor of the body.

Now that the scholars are familiar with the essential structural characters of the earthworm, they will be interested to hear of its habits, and of the work it performs.

The coiled castings which lie upon worm-holes are familiar to everyone. These are due to the fact, that the earthworm, in digging a new hole or deepening an old one, swallows the earth, and passes it through its intestine. This is also one of its methods of obtaining food, since more or less organic matter is contained in all the soils which are frequented by them.

For several years Von Hensen watched these humble animals, and the account he has given us is exceedingly interesting.* According to this observer the worms in the night, and when the weather is damp, come to the surface, and draw leaves, twigs, or the seedlings of plants into their holes. These holes run almost vertically downward from the surface to the depth of three, four, and even six feet. Upon close examination, Hensen found that the worms usually roll the leaves together singly, and draw them into the opening of their holes with the petioles pointing towards the surface. The buried parts of these, thus drawn into the holes to the depth of one or two inches, soon become softened, and in a partly decomposed condition are eaten. In this way the earthworm obtains sufficient food without the assistance of teeth, or hard jaws; solely by the aid of the suctorial power of its proboscis. The deepest part of the hole is thickly set with stones of the size of a pin's head, which are

* See "Zeitschrift für Wissenschaftliche Zoologie." Vol. XXVIII.



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placed there by the worm itself, and when such stones cannot be found, the seeds of early fruits are chosen. In December several seeds were found in one hole which had sprouted. The delicate rootlets of other plants also often run through the whole length of the holes, forming beautiful webs along the walls. Darwin's last remarkable book * throws still more light upon this subject. It is here shown that worms have accomplished an almost incredible amount of work in forming the soil, and preparing the layer of vegetable mould which covers the surface of the land to a greater or less depth in every moderately humid country. This mould might, in some respects, be called worm or animal mould, instead of the usual term "vegetable mould," inasmuch as it "has passed many times through, and will again pass many times through, the intestinal canals of worms." "In many parts of England," says Darwin, "a weight of more than ten tons of dry earth annually passes through their bodies, and is *brought to the surface* on each acre of land." While within their bodies even dry, sandy soil is converted by chemical agencies, trituration, etc., into rich, fine humus.

Stones, fragments of marl, cinders, etc., lying upon the surface of the ground, are, in time, covered by the castings of these animals. In this way the remains of many ancient buildings have been buried and preserved. On the other hand, massive walls have been undermined by worms, and, as a consequence, have subsided.

By other experiments it is shown that these animals

* "Vegetable Mould and Earthworms," 1881.

are only able to distinguish light from darkness, are completely deaf, and have only the sense of touch well developed. Notwithstanding these facts, they exhibit a surprising degree of intelligence in plugging up the openings of their holes or burrows. "They act in nearly the same manner as would a man, who had to close a cylindrical tube with different kinds of leaves, petioles, triangles of paper, etc., for they commonly seize such objects by their pointed ends." . . . "They do not act in the same unvarying manner in all cases, as do most of the lower animals; for instance, they do not drag in leaves by their foot-stalks, unless the basal part of the blade is as narrow as the apex, or narrower than it." In conclusion, Darwin remarks, "It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly-organized creatures."

Nereis virens * is one of the commonest of marine worms. It is found along our coast, burrowing in the mud between tide-marks. Its color is a dull green, tinged with red, and, like the earthworm, it is beautifully iridescent. For class instruction, alcoholic specimens may be used. We now use, in the laboratory of the Boston Society of Natural History, specimens prepared according to Semper's method by Mr. B. H. Van Vleck, Assistant in the Museum, which leaves the specimen dried, but in a state favorable for observing the general anatomy and external characteristics.

Upon examination, the pupils will observe that the body of Nereis is much larger and longer than that of

* A good figure of this species can be found in Morse's "First Book of Zoölogy," p. 83, Fig. 83.

the earthworm, and the rings broader, though fewer in number, and that no segments are altered, or, speaking scientifically, differentiated to form a "saddle," though the first two rings are greatly modified to form a distinct head.

Fig. 3, taken from Turnbull's paper "On the Anatomy and Habits of Nereis Virens," * shows the head and a portion of the body. The first ring (Fig. 3, *hd* 1) is provided with four eyes and two pairs of antennæ. One pair is short and slender (*a* 1), and the other pair, which is also attached to the second ring, is short and stout (*a* 2). Each of the second pair of antennæ (or palpi, as they are sometimes called) has a small, rounded lobe at its end. The second segment (*hd* 2) is larger than the first, and is sometimes called the mouth-ring because it contains the mouth. The skin of this ring is wrinkled longitudinally. This segment bears four pairs of delicate, unjointed antennæ (*a* 3–*a* 6), which are arranged in pairs, the outer (*a* 4, *a* 5) being short, and the inner (*a* 3, *a* 6) the longest. The animal carries these in front or on the sides of its head to aid it in searching for food, and also to warn it of the approach of danger. As in the earthworm, the mouth opens into a pouch or proboscis, which can be turned outwards and used for obtaining food. In many alcoholic specimens this remains permanently everted, showing two large, black, hook-like jaws, one on either side. A number of little teeth may also be seen, arranged in groups upon its inner surface, which look like so many tiny black dots.

* See Trans. Conn. Acad., Vol. III., Part 2, p. 265.

We might infer that Nereis, possessing such a dental apparatus, would be carniverous in its habits; but, though it is very voracious, devouring other worms and marine animals, it does not despise vegetable diet in the form of marine algæ. Turnbull states that it is such a greedy worm, "it will even devour its own immediate relatives if hungry when it meets them;" and one worm, confined by him in a small dish of water, bit itself entirely through near the middle.

The whole body of Nereis is covered with a thin, tough cuticle like that of the earthworm, which may be removed without difficulty. The last segment bears a pair of appendages, called cirri, and is perforated by the anal opening.

In this worm the sexes are distinct. During the breeding season the eggs fill the body cavity, and pass out through openings on the ventral surface which are difficult to detect. The eggs are found in masses, between tide-marks, lying on the mud.

The most important characteristic, and the one which, at a glance, distinguishes Nereis from the earthworm, is the row of appendages which extends on either side the whole length of the body. Every ring, excepting the first two, may be seen to have a pair of these appendages, which are called "paddles," because, though they are used for respiration, they are also locomotive organs. In order that their structure may be more clearly seen, each pupil should cut out one of the largest segments, and examine it with a magnifier.

Fig. 4 shows the paddles, and also the relative position of the internal parts in one segment of the body.

bw represents the body-wall. On either side a paddle (*p*) may be seen, which is divided into a dorsal and ventral portion (*dp* and *vp*); *s*, *s* are the bunches of bristle-like setæ: *r* is the intestine, which runs the whole length of the body; *pc* the space surrounding the internal organs or viscera, and, therefore, known as the perivisceral cavity; *ns* is a nerve ganglion, which is only one of a chain of ganglia, or nerve centres. These extend along the ventral surface of the body, connected by a nerve band consisting of two chords, which unite to form the ganglia. There is a ganglion to each ring, and it supplies nerves to its own segment; *sg* are segmental organs, so called because they are found in nearly every segment of the body. Some of these organs act as kidneys, and others as oviducts.

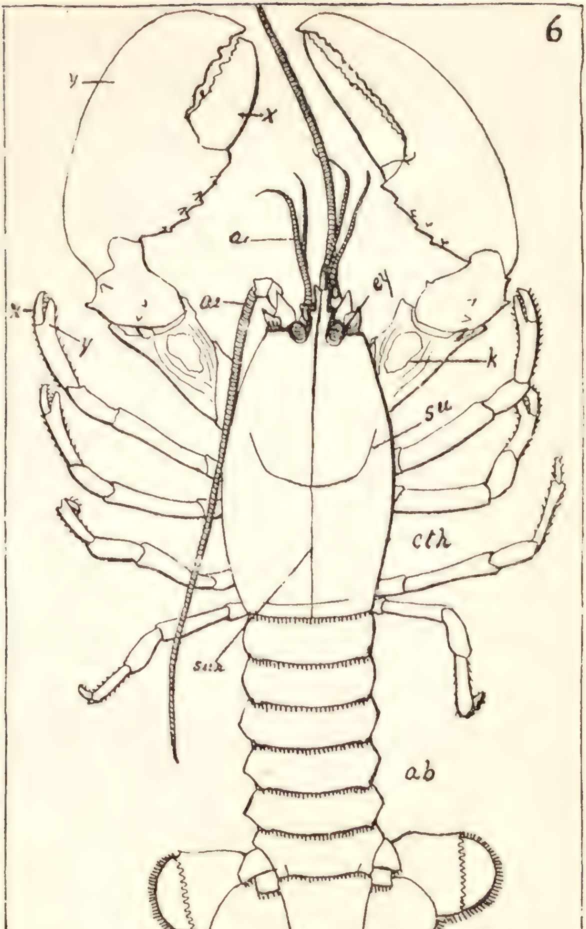
The two principal blood-vessels of the Nereis run the whole length of the body: one (*vv*) along the ventral surface, and the other (*dv*) along the middle of the back, which may be seen in a living specimen. The ventral vessel gives off in every segment of the body, excepting a few in the region of the head, two smaller vessels, one on either side. Each of these divide into two branches, one of which (*vb*) goes to the lower portion of the paddle, while the other (*ib*) passes upward round the intestine. The branch (*bv*) connects with the branch (*db*) in the upper portion of the paddle, and this connection is probably made by the capillary vessels like *co*. The blood, forced backward from the head into the ventral vessel, flows into the branches (*vb*) and (*ib*). The branch (*ib*) receives the blood from the vessel (*db*), and then flows into the dorsal vessel (*dv*), where it may be seen passing in waves towards the head. It is in the numerous blood-vessels of the paddles that the blood is purified by throwing off carbon dioxide and absorbing oxygen from the air in the water. In the living worm the red blood in the minute capillaries may be seen through the delicate, transparent walls of the paddles.

The scholars are now sufficiently familiar with the structure of the worm to understand Fig. 5, which is merely a diagram representing the segmented body of the worm, and the relative position of the different systems: *cs* is the circulatory system, *ds* the digestive system, and *ns* the nervous system.

They will be able to appreciate, moreover, that what is meant by a segment or ring, is an imaginary transverse thick slice through the body, which contains in itself, and carries, on its exterior, the typical organs and appendages of the worm, each ring in the body being, to some extent, a repetition of its neighbor.

They will also be able to understand that the paddles are true appendages formed by the budding out of the walls of the body. This distinction is essential because it is necessary, in comparing the Crustacea with the Worms, to contrast the hard, jointed appendages of the former, with the soft, unjointed paddles of the worm. These appendages can not be compared with the setæ of the earthworm, as it has already been seen that the latter are not true appendages, but simply bristles adapted for locomotive purposes.

It is well to note, however, that in having segmented or jointed appendages the Lobsters differ from the Worms, as do also the Myriapods, Spiders, and Insects. In fact, these types and the Crustacea can be spoken of together under one name, as the Arthropoda, or animals with segmented appendages, and thus contrasted with the Worms.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CRUSTACEA.

Either the lobster, or the fresh water crayfish, is common, and of sufficiently generalized structure to be taken as the type of the class, and one of these should become familiar to the scholars. Lobsters are found below low-water mark along the New England coast, and boiled specimens may be obtained in all the markets.

Fresh water crayfishes are abundant in the rivers of the Middle and Western States, and can sometimes be procured in Eastern markets.* On account of their small size they are more convenient to use, if the class is a large one. With the exception of a few important modifications, the structure of the two animals is the same, so that a description of the lobster will answer for that of the crayfish.†

Every lobster should be placed for examination upon its lower or ventral side, with the head turned from the pupils. The body will then be above, and the organs known as the lobster's appendages will project from the lower surface on either side (Fig. 6). This position is very favorable for making instructive comparisons

* Woodcut No. 22, p. 56.

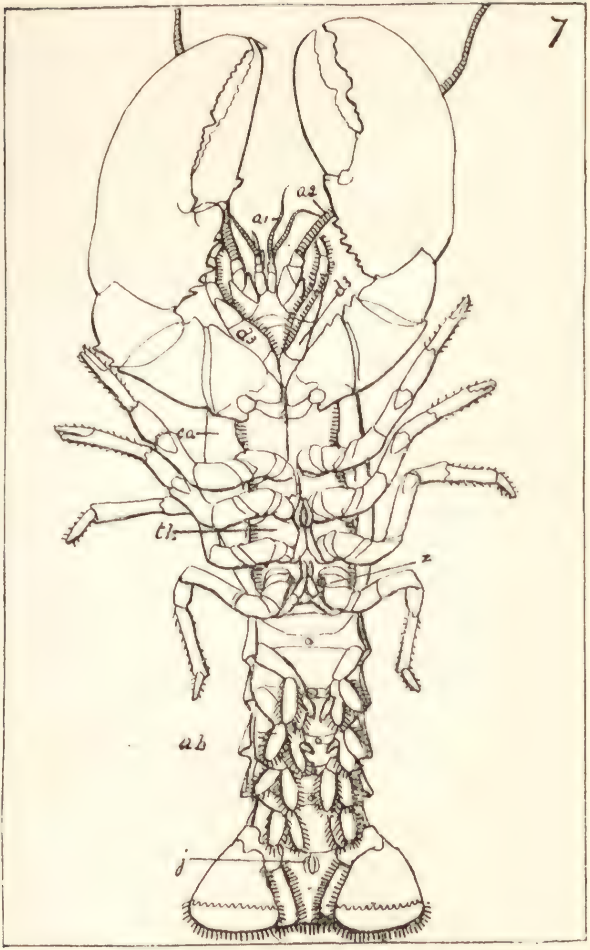
† Huxley's book on the "Crayfish" contains a full and accurate anatomy of this interesting form.

between the structure and symmetry of the human form and that of the creature immediately before the pupil.

The agreements in external symmetry, that it has eyes, feelers, or sense organs, and a mouth forming an anterior end remotely comparable with our own head; that it can be divided by an imaginary plane passing through the centre into halves, equal bilaterally like the human form; that the appendages as limbs for support in walking or swimming are in such bilateral animals, as in our own case, necessarily distributed on the sides; that such bodies which seek their food must necessarily have the mouth and organs of sense at one end, and the organs for locomotion either along the sides or at the posterior end, are all perfectly legitimate and natural comparisons arising from the common characteristics of all animals which move freely, seeking food, self-preservation, and reproduction. The different means and structures which have been produced to meet the common requirements of life upon the surface or in the waters of the earth, are also strongly illustrated by such comparisons, when made with discretion, especially between these free-moving types and such sedentary forms as the Sponges, the Hydra, and the Corals, which have radiate symmetry like plants, mouths or openings above, and no heads.

The body should be studied first, and afterwards the appendages.* The body is seen to be long and cylin-

* Scholars should, of course, be allowed a certain latitude, and this by no means narrow or pedantic, in making their observations, though at the same time they should be led gradually to consider a certain natural order as convenient and essential to the clear presentation of their ideas.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drical in form, and to be covered with a hard, limy crust or shell. The body is divided into two clearly defined parts. The posterior division, the abdomen (Fig. 6, *ab*), which is nearer the pupils, has six distinct, ring-like segments, and a terminal piece, all of which are connected by soft skin, so that they move freely upon each other. The anterior division (Fig. 6, *cth*) does not consist apparently of segments, and is called the carapace, when referring to the visible shell alone, and cephalothorax, when the shell and the thorax inside are both spoken of, because the head and chest appear to be in one piece. The carapace (Fig. 8, *A*, *ca*) terminates in a beak or rostrum anteriorly (*ro*), on either side of which it is hollowed out to give room for the eyes. One important feature of the carapace ought not to be passed over. It will be noticed that an incomplete suture or groove runs from a point near the middle of the back of the shield downward and forward towards the anterior end (Fig. 6, *su*). This suture, which doubtless many of the scholars think is merely an accidental mark, is in reality of importance, as will be seen farther on, when the true character of the carapace is discovered.

In order to arrive at this result, it will be essential to study the appendages and the typical segment. Turn the lobster upon its back, so that the ventral surface, with all the limbs, may be exposed to view (Fig. 7).

It is best to begin the study of the appendages with those of the abdomen, called the swimmerets. Each one of these in the female is seen to consist of a more or less flattened basal portion (Fig. 8, *E*, *h* 1), having

two sections and two flattened lobes (*E*, *h* 2, *h* 3). The outer lobe is smaller than the inner, and both lobes are fringed with short hairs. Those of the first and sixth rings, in both male and female, however, appear to differ greatly from the others. Closer observation of the first pair (Fig. 8, *C*, *f* 1), however, will show the basal section (*h* 1) and the inner terminal lobe (*h* 3), while the outer lobe is undeveloped. In the sixth pair, on the other hand, there is an excessive development of the three parts. The basal section (*h* 1) is broader, thicker, and stouter, and the two delicate divisions have become strong, fan-shaped paddles (*h* 2, *h* 3). The outer lobe is jointed transversely, while both lobes, like those of the other swimmerets, are fringed with hairs.

Having observed the six pairs of appendages, with their six corresponding abdominal rings, the terminal piece, or telson (Fig. 8, *C*, *ab* 7), so called because it means *end*, still remains to be more carefully observed. It is flat and triangular in shape, fringed along its edges, and with the anal opening on its under side. No appendages are found attached to it, and if the lobster were the only crustacean studied, it would be impossible to tell whether the telson was a segment, or a flattened outgrowth in the form of a spine. There is, however, another crustacean, the little crab-lobster, Porcellana, living in the warmer waters of the Pacific and Indian oceans, and also as far north on our coast as Newport, R.I., which can be used to clear up this doubtful question.

This curious little crab possesses a telson, with an unmistakable pair of appendages attached to it, proving

that this part is really a ring whose appendages are wanting in the lobster.

If the pupils have spent sufficient time upon this portion of the lobster's body, they cannot fail to see that it is made up of rings, and that to every ring there is normally a pair of appendages. Also, that all the appendages are built upon the same fundamental type, though differing in the details of form.

The reason for this difference becomes evident when the habits of the living lobster are observed. The appendages of the sixth ring are supported by the telson, and, together with it, form a tail-fin, which is the chief organ of locomotion. This organ, aided by the flexible abdomen, strikes down against the water like a paddle, and with such force that the reaction sends the animal swiftly backwards. By doing work which requires so much effort, the last pair of appendages, as might be expected, are large and powerful. The fifth, fourth, third, and second pairs (Fig. 8, *C*, *f* 2–*f* 5) are also pendant paddles, though less efficient, and are, therefore, similar in aspect, but not as large. They enable small lobsters to swim in a forward direction and assist the older ones in sustaining themselves when floated up from the bottom, where the adults habitually crawl. They are constantly in motion, accomplishing little, however, as locomotive organs in the full-grown animal, but in the female they are used for carrying the eggs during the period of oviferation.

The sexual difference between male and female is shown by the condition of the first pair of swimmerets in the female (Fig. 8, *C*, *f* 1), which, being useless, are rudimentary, and by the corresponding pair which

are intromittent or clasping organs in the male (see Fig. 7), and therefore appropriately developed. The second and third pairs of appendages in the male also have an additional small lobe on the inner side of the larger inner lobe (Fig. 7).

Bearing in mind the general plan of structure discoverable in the lobster's abdomen, the scholars may pass to the cephalothorax. The five pairs of appendages in front of the swimmerets are usually called the walking-legs (Fig. 8, *B*, *c* 1–*c* 5). This number has given the name of Decapoda, or ten-footed Crustacea, to the order. The last four pairs of walking-legs — counting always from the anterior end backwards — have seven sections, and the first pair six sections: the fifth and fourth pairs terminate in short spikes (*x*). Those of the fifth pair are well suited for being used to push and shove the body ahead. The pliability of the terminal joints secure the points of the sections from slipping, and allow the legs to act against them at any angle in shoving the body forward without renewing the hold, until the whole length of the leg and the full force of one step has been economized. The terminal sections or spikes of the fourth pair are larger, more sharply pointed, and thrown out forwards and sidewise. They are hooked into the surface of the ground, and used to drag the body and lift it at the same time. The white worn points of the spikes in both of these legs, and the positions which they can be made to take by manipulation, show how they are used.

At the base of each of the spikes, on the last pair of legs, there is a little spine (*y*), which is really a downward prolongation of the sixth section. It can be felt

very sensibly, though at first it may not be seen, concealed as it is by the short hairs upon its apex and the longer hairs on either side. Passing to the third and second pairs of walking-legs, the scholars will be able to infer from their own observations that the counterpart of this little spine, in each pair, is the jaw-like prolongation of the sixth section (*r*), equal in length to the last section. This growth has taken place on the inner side, and the result is the formation of a clasping organ, of which one section is movable while the other is immovable. Here, then, whenever the animal requires it, the movable part will begin to clamp objects against the immovable portion; or, in other words, rudimentary jaws will be formed, which need only teeth to become capturing or crushing organs like those at the ends of the first pair. These walking-legs are carried well forward under the first pair, and are useful in lifting up, supporting, and moving these heavy parts.

The movable section of the jaws alone is used when the animal is walking upon a hard surface, and then it has the same function as the corresponding seventh section in the fourth limb. The worn, white tip shows again just where wear takes place. The nipping power of these jaws is slight, but they are used to lay hold of objects when the animal is in danger of being dragged out of its hole under the rocks, or from between masses of sea-weed, and are also particularly useful when some fish, or other large prey, struggling to get free, drags it along over open ground. The jaws are then widely opened, and forced deep into the sand, and, together with the other legs, afford a very firm resistance.

The first pair of walking-legs (Fig. 8, *B*, *c* 1) have become modified into large arms. The fifth section (*r*), which corresponds to the sixth of the other walking-legs, is here greatly developed; and it is, apparently, the outer and not the inner portion of this section which is prolonged to form the fixed jaw.

Here, as elsewhere in nature, things are not always what they seem. The big arms in the young are legs precisely similar to the others, but, subsequently, during growth, they are stretched out forward, and used horizontally for grasping, and not used for walking. This constant effort through many generations has doubtless caused them to assume the permanent twist which the joints exhibit in the lobster, and which brings the movable jaw inside instead of outside, as it is in the second and third pairs of walking-legs.

The inner edges of the jaws (it may be either the right arm or the left) bear large, blunt teeth, while those of its opponent are small and sharp. The lobster sometimes anchors itself by the blunt-toothed jaws, which are usually the largest, while it catches and holds its prey with the others. It also uses the large jaws, if necessary, to crush and kill the live prey which is held by the small ones. Most probably, some of the specimens will show a very great difference in the size of the two arms, as it is by no means uncommon for the lobster to lose these appendages and then redevelop them. Dr. Stevenson * relates that a lobster taken prisoner by one of his arms sometimes leaves it in the hands of his astonished captor, and beats a hasty retreat; and that he has also been known to shake off his arms when

* "Boys and Girls in Biology," Chap. VII.

frightened by a loud noise, such as thunder, or the firing of a cannon. Such anecdotes in science-teaching are simply useful as a relief from what ought to be close application to the direct observation of the thing which is being taught. All things are curious to the child, presenting themselves as problems in need of explanation, and he will seek nature for the sake of these explanations, if we do not lead him to think of it as a storehouse of curiosities and mysteries kept on hand for his amusement, in place of what it is, — an original source of knowledge.

Not only is there a difference in the size of these appendages, but it sometimes happens they are much distorted, owing, probably, to injuries received after the lobster moults and before the new shell is formed.

Faxon figures and describes a number of these deformed jaws.* It is interesting to observe the strongly-marked tendency possessed by these organs to reproduce facsimiles of themselves. Most of the extra growths have assumed the form of jaws with serrated inner edges, though the teeth are of no use, as both jaws are immovable.

A more remarkable proof of this inherent power is found in several specimens in the museum of the Boston Society of Natural History, in which additional articulated sections have grown out, and true movable jaws have been formed.

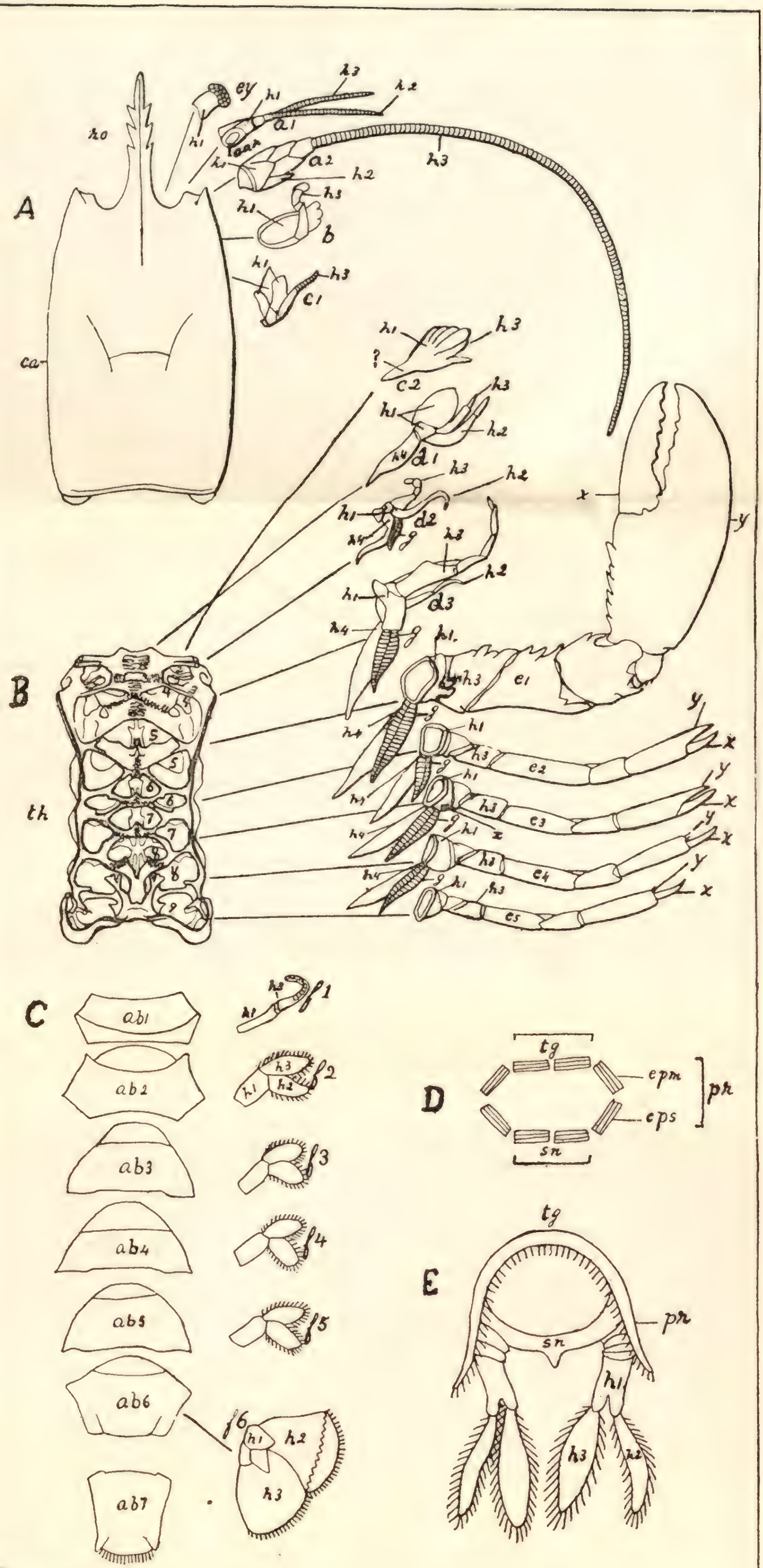
These extra growths are the results of disease occasioned by the irritation arising from bites, cuts, etc., but they illustrate the general law of reproduction. In nature the result of extra growth, whether occasioned by such causes, or by a cell dividing, or a branch or an organ

* See article "On Some Crustacean Deformities," in Bulletin of Museum of Comparative Zoölogy. Harvard College. April, 1881.

budding out, or two bodies uniting "in coitu," is the reproduction of the original image with more or less fidelity, according to the law that *like tends always to reproduce like*. Any dealer in lobsters can obtain these deformed arms, if he chooses to take the trouble.

In front of the large arms are the three pairs of jaw-feet or maxillipeds (Fig. 8, *B*, *d* 1–*d* 3). These are well named, for they are transitional forms between the true legs and the mandibles. The third pair (*d* 3) pick up and hold whatever food lies quietly upon the bottom, at the same time that the large arms are extended forwards, ready to seize and kill the active prey which comes within their reach. The inner portion of this pair of maxillipeds is edged by two serrated blades which hold the food and assist the jaws in tearing off pieces of the right size. It is then apparently bitten and chewed by the other jaw-feet, by the two pairs of little jaws or maxillæ (Fig. 8, *B*, *c* 2; *A*, *c* 1. Fig. 9, *c* 1), which are perpetually moving, and lastly by the hard, strong grinders or mandibles (Figs. 8, 9, 9 *A*, *b*). The structure of the maxillæ, however, shows that they are not of any real use in the matter of chewing. Their inner edges are hairy, and not spinous or toothed, or thickened in any way, as would be the case if they were accustomed to such hard usage.

The mandibles, on the other hand, are powerful, trenchant blades, and are placed one on each side of the mouth (Figs. 9, 9 *A*, *m*), so that they open laterally instead of vertically. This is necessarily the characteristic of all the opposable organs of the lower animals which are formed out of pairs of appendages. Appendages are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normally on the sides, and when brought by function into opposition, and used to cut and grind against each other, they must necessarily move from the sides towards the middle. Taken collectively, the mandibles, maxillæ, and maxillipeds are called the mouth-organs on account of their proximity to that opening, and because some of them do assist in preparing the food which has been found upon the ground, and which has been caught and killed by the big arms. When the closely applied edges of the mandibles are separated, the interior of the mouth is exposed, and just above it is the soft labrum or upper lip (Fig. 9 *A*, *lb*).

In front of and above the mandibles are the long feelers or antennæ (Figs. 6, 7, 8, 9, *a* 2), and next to these the short antennæ (Figs. 6, 7, 8, 9, *a* 1). Lastly, the eyes (Fig. 6, *ey*) are seen at the ends of stout, movable stalks on either side of the projecting rostrum of the carapace.

The pupils have now found fourteen pairs of appendages in the cephalothorax, and the question will be sure to arise in some of their minds, Are these appendages borne upon rings like those of the abdomen, and if so, where are the rings? It is evident they are not on the outside, therefore search must be made for them on the inside. Most young people will be intensely interested in answering this question, and will eagerly remove one side of the carapace, and cut off the feathery gills which obstruct their view, to see whether the walking-legs are fastened to anything they may call rings. They will discover what appears to be, at first sight, a white, thin wall extending along the sides of the cephalothorax, but which, upon closer

examination, looks as if it might be made of the lower portions of several rings which have become soldered together. A number of these rings may be counted, if each appendage is carefully examined at the point of its attachment, and afterwards removed.

The great difficulty, at this stage of the investigation, is to lead the scholars to suspect that these internal rings do not belong to the shield above. That this difficulty may be overcome, let them examine the structure of the carapace. Let them see for themselves that it is a shield formed of the skin folded, and hanging down on either side, so as to cover the cavities in which lie the gills or breathing organs. This can be done by careful use of the knife, or scissors, in cutting away the pendant sides of the shell, or by using lobsters picked out for the purpose, which have the thinnest and most pliable shells, which can be lifted and bent without tearing or breaking; also by placing a fresh or alcoholic specimen in dilute acetic acid until the chalky parts of the shell have been dissolved. In the latter condition it is easy to lift up the side flaps of the shield, and show that they are merely lateral folds of skin.

Another point is to lead them to observe how all the depressions or sutures in the abdomen run straight across the body to the appendages, and how all in the shield run forward towards the mouth. This is shown most plainly by the central, transverse suture (Fig. 6, *su*) which the pupils observed in the carapace at the beginning of the lesson. This suture marks the limits of a ring, and its direction indicates that the ring belongs to one of the pairs of appendages in the

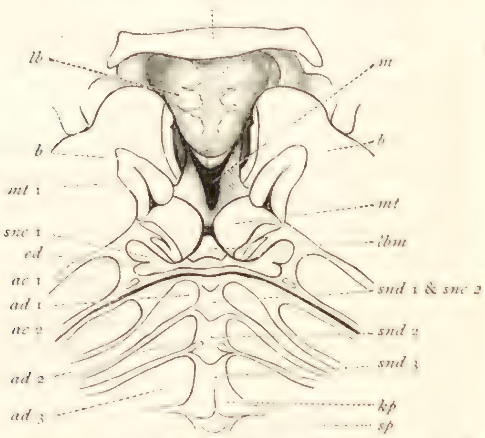
forward part of the body near the mouth, and not to any pair immediately below.

Prepare a fresh specimen by cutting through the sternal part of the cephalothorax, between the first and second pair of maxillæ. Figs. 9, 9 *A*, *cd*, show where the separation should be made. Fig. 9 is a view of the cephalothorax from below. The thoracic appendages have been removed, so that irregular cavities (Nos. 1–9) are seen where the appendages were articulated to the body. *ac* 2 (No. 2) is the place of attachment of the second pair of maxillæ, *ad* 1–*ad* 3 (Nos. 1, 3, 4) of the maxillipeds, and *ae* 1–*ae* 5 (Nos. 5, 6, 7, 8, 9) of the walking-legs. On the right side the first pair of maxillæ are shown. Fig. 9 *A* shows even more plainly the course of the knife along *cd* and between the cavities representing the first pair of maxillæ (*ac* 1) and the second pair of maxillæ (*ac* 2). When this separation has been made, the carapace may be gently raised and torn off; the appendages belonging to the thorax will then remain attached to the under side of that part, and those belonging to the shield itself will come off with it.

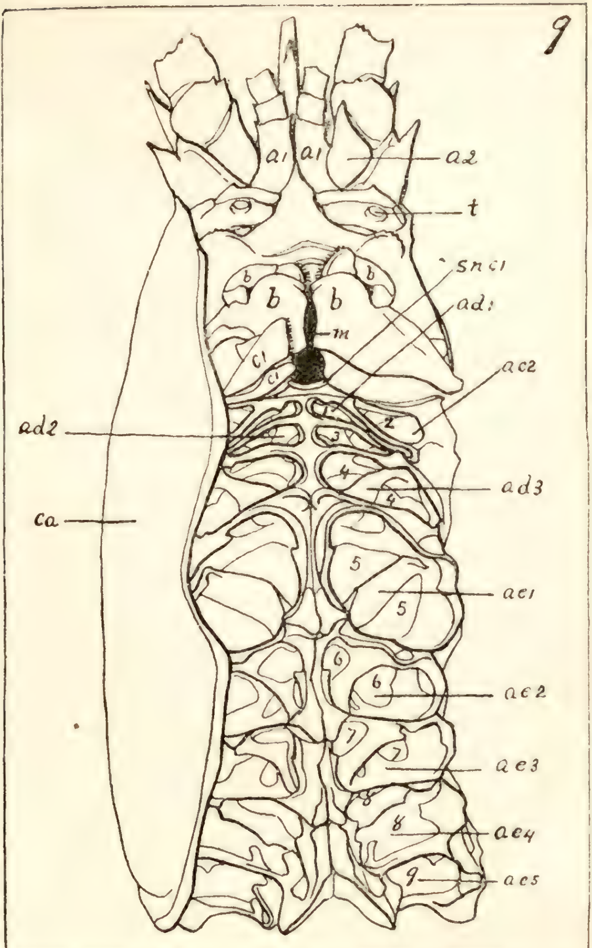
As there are different views with regard to the limits of the thorax, it is necessary to state that the space between the first and second pair of maxillæ is membranous entirely across the sternal region. The continuous calcification of the sternal plates which distinguishes the thorax includes the sternum of the second pair of maxillæ, and the little plate (Figs. 9, 9 *A*, *snc* 1) at the posterior border of the mouth is separated by a pliable hinge from the sternum of the second pair of maxillæ. This also affords attachment to the more or less calcified bases of the leaf-like appendages (Fig. 9 *A*, *mt*, *mt* 1) of the posterior lip or labium (*lbm*) of the mouth.

Fig. 9 *A*. *ed*, is the edge of the thorax; *snc* 1 is the sternal plate of the first pair of maxillæ, which is normally a double plate forking to form sockets for the bases of the metastomata (*mt*), whose broad extremities (*mt* 1) lie upon the mandibles (*b*): *m* is the triangular mouth, and *lb* the labrum or anterior lip, with three pairs of imperfectly-formed plates; *snb*, the sternal plate of the mandibles.

Fig. 9 *A*.



Teachers who consult Huxley's "Crayfish," Eng. Ed., Fig. 39, p. 153, and descriptions, will see at once that he unites the first pair of maxillæ to the thorax, considering the sternal plate to be represented by the first sternum of the united thoracic sterna. This would bring the division of the head from the thorax between the first pair of maxillæ and the mandibles. This is probably an error arising from defective observation. The sternal plate (*snc* 1) can be detected only by careful work on account of its imperfect calcification in young crayfishes, but is readily seen in the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older ones. The separation in the crayfish is also very narrow, a mere line of uncalcified integument, visible under a magnifier. By partially drying, however, and observing from the inside where the calcification is less complete, the plate (*snc* 1) can be more readily observed, and the division also. In this figure the line *mt* ends upon the uncalcified bases of the metastomata, and immediately below this line, where it passes the outer border of the left metastoma, is the hooked-shaped calcified portion or posterior border of the same, which rests upon *snc* 1. *mt* 1 points out the calcified, leaf-shaped, free upper parts of the right metastoma, the membranous part in black. The lines indicating sutures between *snc* 2, *snd* 1, *snd* 2, and *snd* 3, are theoretical, indicating the author's view of the probable position of the sutures; but the line posterior to *sp*, the spinous plate of *snd* 3, was actually visible in one preparation carefully cleaned. The sternal plates are composed of three, and in some cases four, pairs of distinct pieces, the spine or plate *sp* representing the posterior pair, the knobs *kp* the next, and the bridge or beam *snd* may be either one or two pairs, according to the segment. From *sp* to *ed* there are no visible sutures in any of the preparations I have yet seen. The metastomata are not regarded as limbs by the majority of naturalists, but this view is not justified by the facts. They are wholly separated from the bases of the first pair of maxillæ, and are independent outgrowths or buds from the integument, as much as any other pair of appendages; and the fact that the parts of the segment to which they must have belonged have disappeared, or cannot be readily found, is an argument of doubtful weight. It is difficult to account for them unless they are acknowledged to be the remnants of a pair of true appendages which have become reduced to their present state by change of function or disuse. This view, however, cannot be maintained without making this pamphlet too scientific, and therefore not so useful to teachers.

The separation of the sterna is followed out with more difficulty in the crayfish; and this, as well as its small size and the strong attachment of the last ring of the thorax to the first ring of the abdomen, makes it a more difficult subject for general study than the lobster.

Fig. 8, *A*, *B*, shows the shield and thorax after their separation. The thorax is seen from above. The cavities (Nos. 2–9) are marked by numbers corresponding with those of Fig. 9. The articular cavities of the first pair of maxillipeds cannot be seen in this figure, but are represented in Figs. 9, 9 *A*, *ad* 1.

The carapace, thus separated from the thorax, is no longer a cephalothoracic shield, but a cephalic or head shield.* Having thus artificially separated the consolidated thoracic rings with their appendages, the scholars will more readily understand that the cephalic shield is really composed of a number of rings represented by two out of the three pairs of jaw-appendages, the two pairs of antennæ, and the eye-stalks, five rings in all, bearing their five pairs of appendages.

Five rings when the eye-segment is counted, and four when this is not regarded as a ring. Naturalists are divided in opinion on this subject. The disagreement arises, in my opinion, from the false notions entertained of a crustacean ring. A ring is usually looked upon as a segment which arises independently and prior to the development of the region in which it occurs. According to this view, any portion having a later origin is not entitled

* Some naturalists, notably Huxley, are of the opinion that the carapace is under all circumstances a cephalothoracic shield, that portion in front of the transverse or cervical suture belonging to the head, and the part back of it to the thorax.

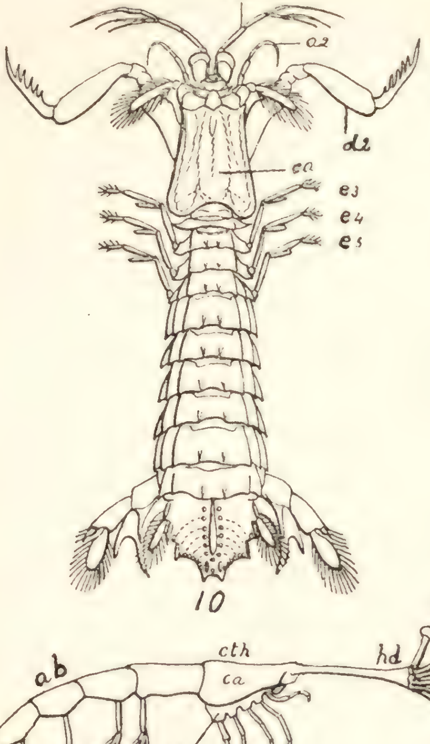
to the name of ring. Observations upon the eye-segment and eye-stalks of the lobster tend to prove that the former is not a primitive division of the body, like the other segments, but that it and the eye-stalks are later developments. Whether, however, the portion to which the eye-stalks are attached grows in the same way as the other rings, or in a different way, it is a fact that in the adult lobster there is a distinct eye-segment bearing the distinctly articulated appendages, the eye-stalks. Furthermore, in Squilla (Fig. 10), a crustacean found on our coast south of Cape Cod, there is a distinct, movable eye-segment. The researches of Professor W. K. Brooks appear to settle this disputed question by showing that of the three anterior segments in Squilla the eye-segment arises first, and the two antennal segments afterwards. These three rings are developed, according to the same authority, from the anterior end of the consolidated cephalic region. This looks as if they were quite distinct in their mode of origin from the other rings, though, at the same time, they are true segments, each bearing its pair of appendages. The teacher, therefore, may count five rings, and five pairs of appendages belonging to the cephalic region of the lobster.

The teacher should always carefully distinguish between the stalk itself and the eye. This association is not common to all the Crustacea, but only to one division, as will be seen in Gammarus and other lower forms. The large compound eyes are normally only secondary developments, and though functionally more powerful and useful, are supplemented by a pair of single eyes, which are found in the young forms, and still exist in some adults, as in the Limulus, or horse-shoe crab (Figs. 31, 32), common on our coast. These are the primitive eyes, though superseded and rendered useless in the adults by the functional compound eyes.

That the rings of the head have become consolidated and extended backwards, covering up the rings of the

thoracic region, while, on the other hand, the rings of the thoracic region have also been crowded forwards, is proved by comparison with lower forms. Thus, in Squilla (Fig. 10), and especially in Lucifer (Fig. 11), the forward segments of the thorax are less crowded, and finally in Nebalia (Fig. 12), they are not crowded at all. In this remarkable type is seen the typical distribution of the segments, which are described in all the books as if equally characteristic of these forms and of the lobster and higher Decapoda. There are distinctly six appendages to the head, their rings consolidated and the shield developed backward, but not yet soldered to the thorax. There are also eight appendages to the thorax with every ring definable in the body, and in the abdomen eight rings, six only having appendages. Embryology shows that Nebalia belongs to the same large group as the lobster and Squilla, and leaves but little room for doubt that the body of the Crustacea is divisible into three regions, — the head, thorax, and abdomen. Also that the two former are concentrated in the Decapoda so as to be almost indistinguishable; and to such an extent that, in the lobster, in place of counting eight rings in the thorax and six in the head, we have to count nine in the thorax and five in the head. The usual mode of stating this in the books leads the general student to look for precisely the same number of rings in the thorax, head, and abdomen in all forms of Crustacea, whereas they vary in the different forms.

Five cephalic rings in place of six have become consolidated, and the lateral and dorsal pieces have spread backwards in the lobster, until they have cov-



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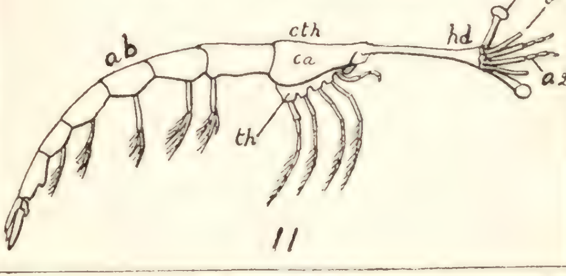

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ered the nine thoracic rings bearing the walking-legs, the maxillipeds, and one pair of maxillæ. A dried and cleaned shell from which the teacher can remove the thorax, with the legs, etc., will be found useful at this stage of the lesson.

Before studying the elements of a ring, which will make the subject of the consolidation of segments clearer, the appendages of the cephalothorax, which still remain in good condition on one side of the body, may be compared with those of the third abdominal ring (Fig. 8, *E*), in order to determine whether or not they are built upon the same plan of structure.

For this comparison it would certainly be most natural to begin with the eye-stalks and go backward, or else with the last pair of walking-legs and go forward, but, in either case, there would be much difficulty in recognizing the similarity of structure which really exists, though it is most successfully disguised by both of these pairs of appendages. Now if the resemblance is less completely masked by any one of the fourteen pairs of appendages, it would be better to begin with that pair wherever it might occur. Just such appendages are found in the third pair of maxillipeds (Fig. 8, *B*, *d* 3). The pupils will recognize the basal section (*h* 1), with the two parts corresponding to the two lobes. The inner lobe has taken the form of a little walking-leg (*h* 3), while the outer lobe has become slender and tapering (*h* 2). A fourth and additional section (*h* 4) is articulated to the basal portion, and extends upward into what is known as the gill-chamber. This section bears one of the feathery gills (*g*).

Examining now the five pairs of walking-legs, it is seen that they represent the inner section (*h* 3), while the outer section is undeveloped. The fourth section (*h* 4), bearing a gill (*g*), is found in all excepting the last pair of walking-legs.

Turning to the second pair of jaw-feet (*d* 2), the four sections are quickly recognized: in the first pair (*d* 1) the fourth section does not bear a gill.

The scholars have now found six gills fastened to six of the thoracic appendages, and they may also observe twelve others attached to the consolidated thoracic rings, making eighteen gills on each side. When the animal is walking or feeding, the gills attached to the legs are kept in motion. In this way a greater extent of surface is brought in contact with the water, and the aeration of the blood more speedily effected.

The sections of the second and first pairs of maxillæ have become modified into delicate, leaf-like forms, in which it is not as easy to distinguish the separate parts. Care should be taken in removing the second pair of maxillæ not to injure the spoon-shaped organ (Fig. 8, *B*, *c* 2, ?) attached to each maxilla. This is marked with an interrogation point, as it is uncertain whether it represents the section *h* 4 or the united sections *h* 2 and *h* 4. This organ is a hinged valve, and it pumps the water through the gill-chamber, whereby a fresh supply is induced to flow in under the carapace. In the mandible (*b*) the basal section (*h* 1) is greatly developed, and the inner lobe is represented by the little jointed palp upon its upper side (*h* 3).

Examining the large antenna (*a* 2), it is easy to detect the basal section (*h* 1), with its long, slender, many-jointed inner division (*h* 3) and scale-like outer division (*h* 2). An opening (Fig. 9, *t*) will be seen on the ventral side of the basal section of both antennæ. These are the outlets of the two large "green-glands" which are situated within the head, and are supposed to perform the function of kidneys. In the little antenna (*a* 1) the inner and outer

divisions (*h* 3, *h* 2) are similar in general appearance. Lastly, the eye-stalk (*ey*) is supposed to represent the basal section (*h* 1), the three appendages borne on this not being developed.

On the upper side of the basal section of the little antennæ are the ears of the lobster (Fig. 8, *A*, *a* 1, *ear*). These organs are detected externally by a small oval space of a clearer aspect than the rest of the section. This space is protected by hairs, and when these are scraped or cut away an opening is seen on the upper inner edge, through which a bristle may be passed into the interior.

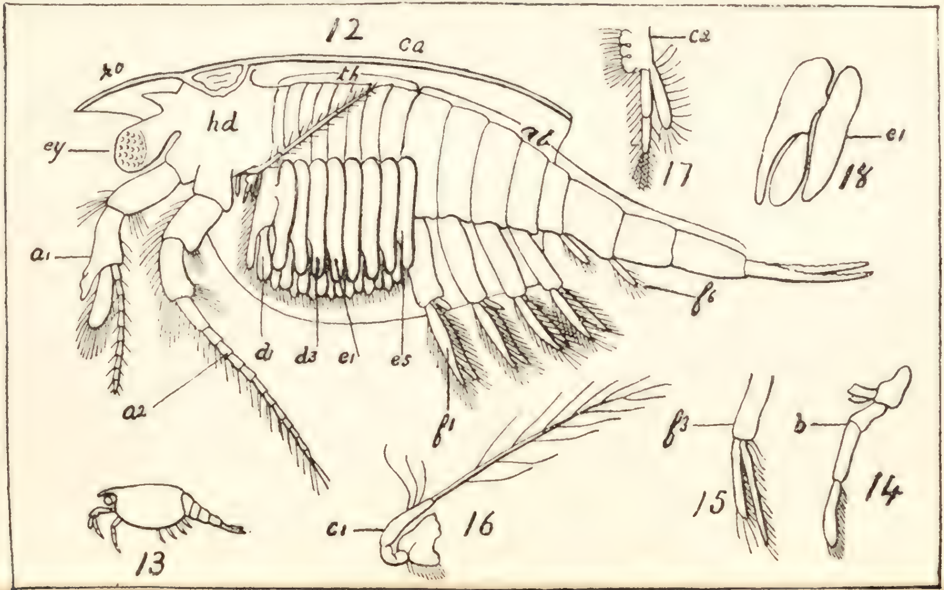
If, now, the soft, external membrane covering the oval space is carefully removed, together with the calcified portion of the section and the muscles beneath, a white, semi-transparent sac is seen, in which one end of the inserted bristle will be detected. Opening this sac, it is found to contain very small grains of sand with other foreign matters and a thick fluid. A projecting ridge is also observed, covered with fine hairs, which are connected at their bases with branches of the auditory nerve. A sound-wave sets the sand particles in motion, the vibrations affect the hairs, and the impressions of these vibrations are conveyed along the auditory nerve to the brain.

So far, the pupils have discovered, in spite of excessive growth and differences of position on the one hand, or of non-development on the other, one plan common to all the appendages.

The resemblance existing between the appendages arranged along an axis like those of the lobster is known as serial symmetry, and one appendage can be called the serial homotype of another, and the leg of

one side can be called the lateral homotype of the same organ on the other side. The lobster's appendages and rings are also excellent illustrations of what naturalists mean by the use of the word homologous: they mean organs which, in different animals, are similar in position with relation to each other and in the elements of their structure. Thus the antennæ and mouth-parts in Nebalia (Fig. 12), Branchipus (Fig. 39), and Lobster (Fig. 8) are all respectively homologous to one another, or the corresponding abdominal appendages, or the stalks of the eyes, but these last are not homologous with the sessile eyes of the Gammarus (Fig. 21) or of the Limulus (Fig. 31). The compound eyes themselves are not in the same relative positions in all Crustacea, so far as we know, and they on this account are considered as homologous organs provisionally, whereas the primitive eyes are undoubtedly homologous.

In order to study the elements of a ring, the third abdominal segment should be separated from the others (Fig. 8, *E*). Its upper portion, called the tergum (*tg*), is seen to be convex, and much broader than the almost straight ventral beam or sternum (*sn*). The sides of the shell are prolonged downward, forming a double projecting piece called the pleuron (*pr*). In reality, the ring is much more complex in structure, as is shown by Fig. 8, *D*, where the tergum, pleuron, and sternum are each seen to be composed of two pieces. Though the sutures marking the limits of all these pieces are not seen in any single ring, yet there are marks on the outside of the shell which show all the divisions. Thus along the middle of the shield is the mark of the median suture (Fig. 6, *sur*) of the tergal plates, and on the ventral side, the middle



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suture which divides the two sternal plates may be observed. On the abdomen the median suture cannot be detected, but the lateral borders of the tergal plates are well defined, though this is due rather to the lighter color of these parts than to any other cause.

While we can thus describe a typical ring, it must not be forgotten that in the sterna of the thorax there is more than one pair of plates. In fact, the number of plates is, like other parts, a variable quantity, and in following the text-books this fact should be borne in mind.

Comparing now the thoracic segments with the third abdominal ring, the sterna and pleura are recognized, while the terga appear to be wanting. This, however, is denied by some, who consider that these rings have simply opened along the middle of their tergal portions and spread apart. This, of course, has brought the two halves of each tergum on opposite sides. We can only account for this splitting of the rings, if this occurred, and their existing forms, by supposing that their dorsal portions were not needed for the protection of the internal organs, as in the abdominal rings, the carapace here being quite sufficient for that purpose.

The consolidation of the rings of the cephalothorax is usually accounted for by the theory of cephalization or head-making. This theory, originated by Professor Dana of New Haven, assumes that in the higher forms of Crustacea and other types there is a concentration of parts and organs towards the head, and a corresponding series of modifications introduced, enabling these to subserve the purposes of the head better, and dividing them from the walking-limbs, etc. Yet this theory does not seem to offer an adequate explanation for all the facts observed. In many Crustacea, Limulus (Fig. 31), etc., the cephalic and thoracic appendages have become concentrated around the mouth.

In Squilla (Fig. 10), of which mention has already been made, the head region has been well defined, and consists of three distinct, movable rings, bearing their appendages, the eye-stalks, and two pairs of antennæ. This region is therefore quite independent of the mouth, which lies some distance back of it. The mouth, with its appendages, is followed by the thoracic region, while the latter is only in part concealed by the carapace, so that its unconsolidated rings may be readily counted.

Following the thorax is the abdomen, the most conspicuous region of the body, with its large, well-developed swimmerets, which bespeak for Squilla excellent powers as a swimmer. It is unfortunate that specimens of Squilla cannot be easily obtained, as it is a much simpler expression of the crustacean plan of structure. In the strange type known as Lucifer (Fig. 11), the eye and antennal segments are prolonged very far in advance of the mouth, and show the extreme modifications of this tendency.

Comparing the lobster with the Squilla and Lucifer type, we find that, in proportion to the size of the two animals, the abdomen of the lobster is much smaller and shorter, and the swimmerets (excepting the last pair) smaller and weaker. The thorax has been carried forward under the carapace, while the walking-legs have become large and strong. The three most essential of the cephalic segments have been carried back towards the mouth, and these, together with the mandibular and maxillary segments, are described as the cephalic region, though, more strictly speaking, they might be named the mouth region. The mouth,

in fact, appears to be the centre around which the cephalic organs are concentrated. We can readily understand that the hunt for food might tend, in the course of many generations, to bring into activity more and more of the appendages in the vicinity of the mouth, and that this might result, not only in a forward concentration of these appendages, but also in such a modification of their structure as would fit them to be more useful servants of the mouth. Yet this effort alone would not be sufficient to account for that exceeding concentration of structure observable in the highest Crustacea. Other effects must be taken into consideration, namely, those which would arise from efforts to walk. It is evident this desire could not be gratified without throwing more work on those appendages which were best suited by their position and structure to bear the weight of the body. The enlargement and increased strength which would surely follow would bring the forward part of the body into greater use, and would render the swimmerets and the abdomen, which are so powerful and necessarily large in a swimming animal, less and less functionally useful, and cause them to decrease in size in proportion as the animal became more and more a walking type. In order that a swimming Crustacean should change into a walking form, the two ends of the body must be shortened, or, in other words, there must be a concentration forwards of the posterior part, and a concentration backwards of the anterior portion, so that the centre of gravity may be brought into proper relation to the bases of support.

This is admirably illustrated by the crabs, as will be

seen farther on. Thus it appears that it is not the law of cephalization, but the effort to obtain food in the most suitable way, and to meet the requirements of the laws of equilibrium, which concentrates the growth in some of the regions and appendages, and warps or suppresses others through disuse. The animal thus becomes able to balance itself upon the smallest number of supports possible for its type of structure, and also acquires the greatest attainable facility in moving and turning on its appendages or supports, a result which is essential to the perfect development of all the higher forms of walking types. The equality of the segments and the elongation of the body in the crawling types like the worms can be strongly contrasted with this concentration. The equality of the efforts made by each ring in the sinuous movements of the body on the surface, or through the mud or ground, is here evidently the cause of the similarity, just as the equality of the abdominal rings in the lobster, and their appendages from *f* 2 to *f* 5 inclusive, may be attributed to their performance of identical functions in the act of swimming.*

Owing to the large size of the lobster, only a little care and patience are needed to study the different internal organs. In dissecting the animal, it is desirable to have unboiled specimens. The scholars should

* For information with regard to the specific effects of use, see the following papers by John A. Ryder: "On the Laws of Digital Reduction," American Naturalist, Oct., 1877; "On the Mechanical Genesis of Tooth Forms," Proceedings of the Acad. of Nat. Sciences, Phila., 1878; also paper on the same subject in American Naturalist, July, 1879.

remove, by means of a dissecting-knife or a pair of scissors, the dorsal portion of the carapace, and of each abdominal segment, observing, as they do so, the red skin which covers the body and forms the shell above it. The powerful muscles of the abdomen lie beneath the red skin, extending upward on either side of the cephalothorax. Some time may be spent in examining the different muscles, and in determining how they act. They should then be removed sufficiently to expose the blood-vessels. The heart is a spongy mass, surrounded by a sac, and situated in a hollow space or chamber formed in the posterior part of the cephalothorax. It lies immediately under the skin, and may be distinguished from the other organs by its color. Five arteries are given off from the heart anteriorly; the middle one passes to the eyes, the next partly to the antennæ, the succeeding two to the stomach and liver. Posteriorly, one artery arises; this branches into two, one of which extends through the abdomen, above the intestine, while the other bends down and connects with the sternal artery which runs along the floor of the body, and cannot be traced till the digestive organs and muscles have been removed. On taking out the heart the pupils must cut the sternal artery; they are then ready to study the digestive organs. A probe may be passed from the mouth into the stomach, which is an extremely interesting organ to examine. It is divided into two parts; the larger or cardiac portion is a sort of mill, where the food is ground by an apparatus familiarly known as "the lady of the lobster." The smaller division, or pylorus, is a gate-keeper in the form of a strainer, which will not permit a single

large particle to enter the delicate tube of the intestine. Opening into the pylorus on either side are the large yellowish-green lobes of the liver. The straight intestine traverses the whole length of the abdomen, and ends in the last segment, like the intestine of the worm.

On removing the digestive system, two large organs remain, which are dark green in the uncooked lobster, and red in the boiled specimen. These are the ovaries, which open on the basal joints (Fig. 8, *B*, *c* 3, *z*) of the third pair of walking-legs. The eggs come out of these two openings, and are surrounded with a sticky substance, by which they become fastened to the hairs of the swimmerets. Here they remain till the young are hatched. If the lobster is boiled before the eggs are laid, they turn red, and are known as "the coral," from their resemblance to coral beads. The reproductive organs of the male are smaller and longer than those of the female, and open on the basal joints of the last pair of thoracic appendages (Fig. 7, *z*).

Thus not only the external parts of rings, but nearly all the vital organs of the lobster, are concentrated in the cephalothoracic region. Even the generative organs have been crowded forward, so that the abdomen is really little more than a tail, or muscular organ, for propelling the animal through the water. This being the case, some naturalists prefer to call it the "tail," or "post-abdomen;" but these names involve the scholars in difficulties when they begin to study insects, so that it seems desirable to retain the name of abdomen, at the same time bearing in mind its tail-like function.

In order to see the nervous system of the lobster, all the organs and muscles must be removed. The nerves of the abdomen will be exposed first, as those of the cephalothorax are entirely concealed by a hard, limy secretion, which forms a "false bottom" to this region of the body. When this has been cut away, a double white cord will be seen extending along the floor of the body, and connecting thirteen ganglia. The anterior ganglion is the largest, and is the lobster's "brain." *

Allusion was made to the moulting of the lobster when speaking of crustacean deformities. This process of moulting, or of shedding the shell, is one of the important characteristics of animals encased in articulated armor like Crustacea and Insecta, it being, in fact, the only way in which provision is made for the increase in size of the body by growth. The lobster sheds its shell whenever the old one becomes too small. The number of moults in a given time varies with age, the young lobster shedding its shell oftener, while the large one is supposed to moult, at least, once a year. When the animal is aged it ceases to moult, and barnacles, mollusks, and other creatures have time to become attached and grow on the shell.

Only three descriptions have been given of the operation, and these were written by naturalists who received their information from unscientific witnesses. The mode of moulting varies, the animal either crawling out of his shell, as the crayfish does between the carapace

* For a full description of the anatomy of the lobster and crayfish, see Huxley, "Anatomy of Invertebrated Animals"; Huxley, "The Crayfish"; Packard, "Manual of Zoölogy"; Rolleston, "Forms of Animal Life."

and first abdominal ring, or by splitting open the carapace along the middle line of the back (Fig. 6, *sur*). In a specimen observed at the island of Martinicus, off the coast of Maine, the fissure occurred between the carapace and the first ring of the abdomen, as in the crayfish. Through this opening the large arms, the walking-legs, and whole forward part of the body were drawn. This operation was performed, apparently, without the slightest difficulty. The animal laid on its side, and its tail was bent sharply under the carapace, and no motions of the abdomen were seen. The whole operation was accomplished by the muscles of the forward part of the body, which, gradually bending and bulging more and more outwardly, finally withdrew the cephalothorax completely, and with a motion or two switched off the abdominal casing. The whole time occupied by the moulting did not exceed fifteen minutes. Immediately after the moulting, the size of the large arms was considerably less than the outside measurements of the shell, and so also were all the parts. They were exceedingly hard and firm at first, the watery aspect usually attributed to the newly-moulted Crustacean not appearing until some hours after the shell was actually cast off. The effort to keep the animal alive until his new shell had completely hardened, failed, and at the end of two days he was found dead. The operation of forming a new shell takes probably about a week, though the time is very variable, according to the conditions under which the animal is living. The ease with which the lobster withdraws its body and limbs is owing to the absorption which takes place, especially on the inner sides of the great arms,

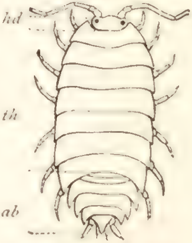
in an area (Fig. 6, *k*) marked by a series of concentric lines caused by the excess of chitinous matter, and at various parts of the internal rings of the thorax, at the bases of the legs, and along the sutures of the carapace. When this absorption proceeds far enough, the carapace splits under the pressure, otherwise it remains whole, as in the case above described.

EDRIOPTHALMIA.

Isopods.

It has been thought best to treat only of those forms which may be easily obtained and may be most directly compared with the lobster in certain logical sequence in this part of the Guide, and defer even the brief mention which is possible of the lowest forms of the Crustacea until this was finished. The Isopods are found on our coast between tide-marks, and are related to the common "sow bug," Oniscus (Fig. 19), so often seen in cellars, and common also beneath stones, boards, etc., and other damp places. A species of Asellus also occurs in our fresh waters which is like the Oniscus, and can be used as a type. They are well represented by the Idotæa (Fig. 20), which is very common in eel-grass, beyond low-water mark. Its body is flattened, and the abdomen and thorax are continuous, and the freely movable rings of the latter may be easily counted. The carapace is

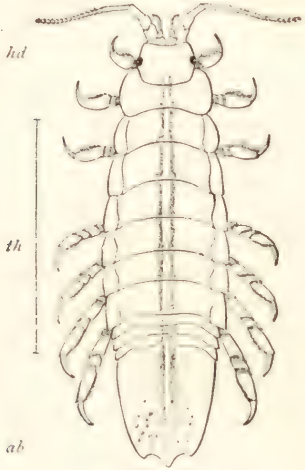
Fig. 19



Oniscus (after Morse).

reduced to a small head-shield. The appendages have undergone less modification than those of the lobster, and are therefore simpler in structure. The swimmerets are under the abdomen, and the first pair forms a cover for the others. The gills are the two leaves of

Fig. 20.



Idotæa irrorata Say.
(After Emerton.)

The line shows natural size of species.

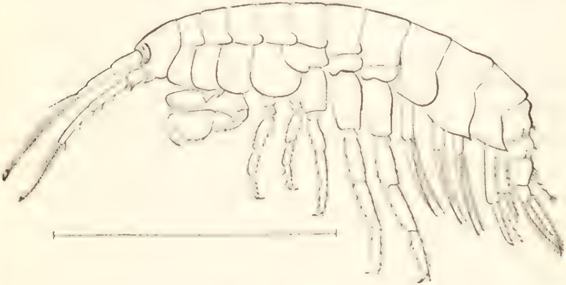
the swimmerets attached to the bases of the posterior pairs. The seven pairs of walking-legs are very similar to each other, and this is one of the distinguishing characteristics of the order, as might be inferred from its name of Isopoda, or equal-footed Crustacea. The

three anterior pairs are directed forwards, and the remaining four pairs backwards. The Isopods move with the head in advance.

Amphipods.

The largest and finest specimens of the typical Amphipods are those known as beach-fleas, the Gammarus ornatus (Fig. 21), and they are found under stones

Fig. 21.



Gammarus ornatus Edw.
(After Emerton.)
The line shows natural size of species.

and sea-weed at low-water mark along all our principal beaches. The body of Gammarus is composed of a succession of rings, which remind the pupils of the abdominal rings of the lobster, being not unlike these in form, and freely movable upon each other. The seven posterior segments, constituting the abdomen, bear the six pairs of swimmerets. In Fig. 21, five of the swimmerets are represented on the left side, and one on the right.

In front of the abdomen there are seven distinct rings which carry seven pairs of appendages, and in front of these is one pair of maxillipeds. The first ring of the thorax is only represented by remnants of its ventral and lateral portions, but bears the first pair of maxillipeds. The remnants are tucked away between the cephalic shield and the second ring of the thorax, and are entirely concealed from view until closely looked for. These eight rings and their appendages form the thoracic region. In the Orchestia agilis,* a species which lives in holes on the beach, the first thoracic ring and the first pair of maxillipeds are clearly seen. In this animal the last three pairs of swimmerets are used for leaping. Both the Orchestia and the Gammarus leap or swim head first, but while the former can stand upright, the latter, on account of its narrow body, can only swim lying on its side or back down, the appendages being brought closely together by the lateral compression of the body. The first two limbs of the thorax are used for clasping, a curious jaw being formed by the bending back of the terminal section against the next inner one.

Attached to the bases of the thoracic limbs are the sac-like gills. The carapace is reduced to a small head-shield, as in Idotæa, so that the thoracic rings are not covered, and, with the exception described, may be easily counted.

The head looks like one segment, but it carries two pairs of antennæ, one pair of mandibles, and two pairs

* See Annual Reports of the United States Fish Commission, 1871–72, Pl. IV, Fig. 14.

of maxillæ, which would indicate that the head-shield is really made of five consolidated rings. It will be noticed that the eyes are set in the head, and not borne upon stalks. For this reason, the Gammarus and the Idotæa are placed among the sessile-eyed Crustacea, Edriopthalmia, while the lobster belongs to the stalk-eyed division of the class, Podopthalmia.

PODOPTHALMIA.

This general division of the class includes, among the forms already described, Nebalia and a host of similar animals, most of them represented by fossils, the genera Lucifer, Squilla, and the like, of the order Stomapoda, as well as the following groups belonging to the order of the Decapoda.

Anomoura.

This group, in so far as its range of form and structure is concerned, is in reality equivalent to both Macroura and Brachyura. The habits of the hermit-crab (Figs. 22, 23) are very instructive to children. The arms are used both for walking and getting food, etc., the second and third pairs of thoracic limbs for walking alone, and the fifth pair are crooked and help to hold the animal in the shell, the fourth pair being probably useful in this way also. The segment of the fifth pair is wholly free from the thorax, and seems to belong to the abdomen, when viewed from the dorsal side. The abdomen is soft and bag-like. The first ring has no appendages; the second,

third, and fourth have limbs on the left side only fo holding the eggs during the period of oviferation; th fifth is extremely small, and shows on the left side jus above *f* 6 in Fig. 23. *f* 6 are the only complete pair and they are modified into claspers for holding th

Fig. 22.

Eupagurus policaris (after Morse).

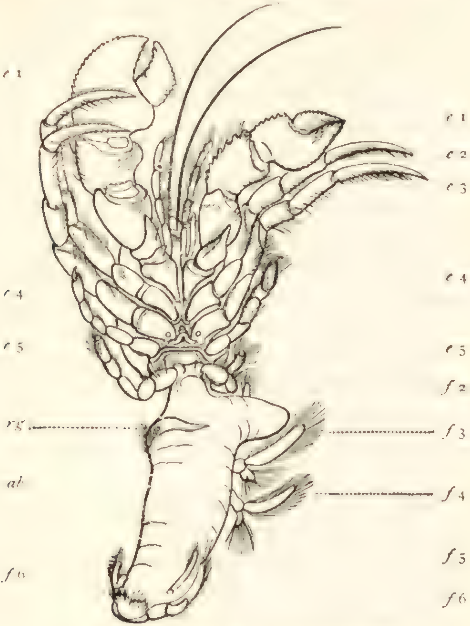
The hermit-crab, as it appears when partly protruded from the shell in the act of walking.

animal in a shell. *rg* is a hard ridge, which, like the projection on the opposite side, is useful in holding against the columella of the shell. The crab has adopted the curious habit of depending upon the shells of sea-snails for protection, and the softness of the abdomen is due to the effect of the artificial covering of this part, as may be seen by comparison with the less protected abdomen of Lithodes.

Usually, empty shells are chosen, though sometimes

other hermit-crabs are killed and the shells appropriated. Two will often desert their old shells, and, making for the same prize, fight desperate duels for its

Fig. 23.



Eupagurus policaris (after Morse).
Seen from ventral side when out of the shell.

possession. As soon as the house becomes too small for the growing animal, it is deserted, and a larger one selected. It is interesting to watch one of these crabs as it goes about trying on shell after shell, as one does

the ready-made coats in a clothing store, until it finds one to fit, when it slips in and closes the entrance with its large arms. The habit of hiding either a part or the whole body in holes arises from the desire for protection, and we can readily understand how such animals, seeking protection, should gradually lose the parts which had been made useless by the new habit, or should modify others which still remained useful, or perhaps even develop new organs. In this connection the great Birgus, or Palm-thief, is of special interest. This is a land-crab which inhabits the islands of the Pacific and Indian oceans. Instead of seeking for safety in deserted shells, these crabs make deep holes in the ground, beneath the roots of cocoa-nut trees. In Woods' "Homes without Hands," the crabs are pictured in the act of husking and feeding upon the nuts. The jaws of the first pair of legs do most of the hard work in husking the fruit, and the meat is taken out through the soft "eyes" of the nut by the hinder pair of walking-legs after they have been bored out by the jaws.

The crabs go to their original habitat, the sea, to lay their eggs, and the young are hatched and live for some time on the coast. The Birgus is very instructive, as it illustrates how a marine animal may become adapted to live on the land and breathe air instead of water. It appears to have accomplished this by changing a part of each gill-cavity into a lung.

According to Semper,* each gill-cavity consists of a

* Zeitschrift für Wissenschaft. Zoölogie, Vol. XXX. Translated in International Scientific Series, "Animal Life as affected by Natural Conditions," by Carl Semper, 1881.

lower and upper portion; the lower portion is the smaller, and contains the true gills, while the roof or dorsal part "is to be regarded with certainty as a lung." In the crabs examined, the lateral cavities always contained air, and only sufficient water to keep the parts moist. This small amount of water is necessary, as it is a well-known fact that the breathing organs of all animals can only absorb oxygen in sufficient quantities when the surface membranes are kept moist.

The "lungs" are richly supplied with blood-vessels. The situation of these vessels, the direction of the flow of blood through them, and the fact that this blood cannot be regarded as arterial, all tend to prove that these crabs breathe by means of their lungs, and not by their gills.

"Should the gills in the gill-cavity of a land-crab," remarks Semper, "become yet more reduced, and at last entirely disappear, then would the simple gill-cavity be exactly equal, physiologically, to a true lung, as it is in the air-breathing snails, though it might still be called a gill-cavity, because it would be such morphologically."

The highest members of the Anomoura group, Lithodes, are so like some of the true crabs, especially the spider-crabs (see p. 61, Fig. 29), that they were formerly classified with these in the same family. They have the same form and general structure, but with only four pairs of functionally useful walking-legs, the fifth pair being very small, and the fifth ring to which these are attached being separated from the other thoracic rings, as in the hermit-crab. The abdomen is bent under the body as in the true crabs, and covered with soft skin on the inside, where it is protected, and with three rows of plates on the outside, where it is exposed, the terga in the centre, and the two rows of epimera on the sides.

Macroura.

This division, to which the lobster belongs, has already received its full share of attention, and need not be mentioned except so far as is necessary to show that

Fig. 24.

Astacus fluviatilis (after Morse).
Crayfish.

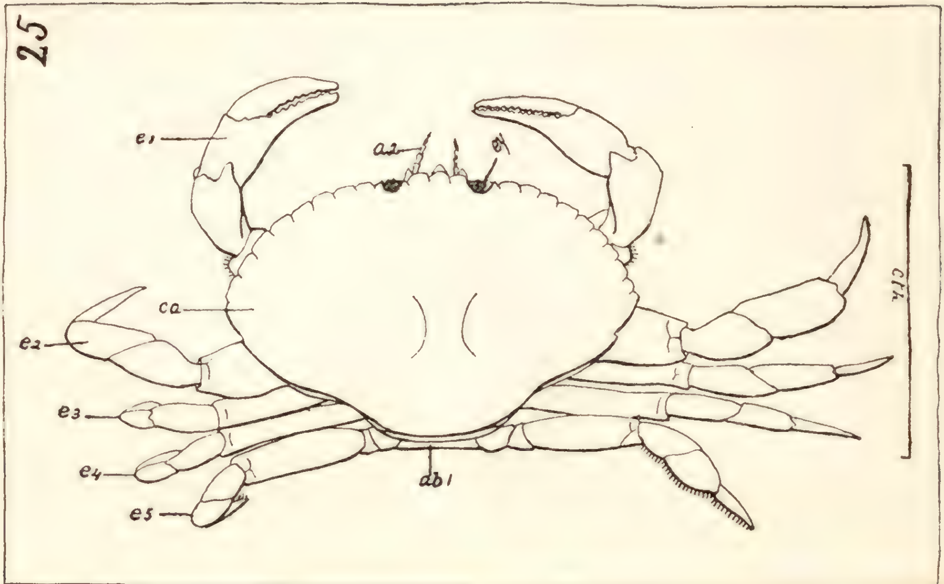
its proper position in the classification is in close association with the highest group of the Crustacea, the Brachyura, common edible crabs and the like.

Brachyura.

We now pass to the crabs proper, or to the highest of Crustacea. Figs. 25–27 represent our commonest species of the genus Cancer. By this time the pupils ought to detect similarities with readiness, and find no great difficulty in comparing the crab and the lobster.

The abdomen, the first ring of which is seen from above (Fig. 25, *ab* 1), and all the rings from below

25



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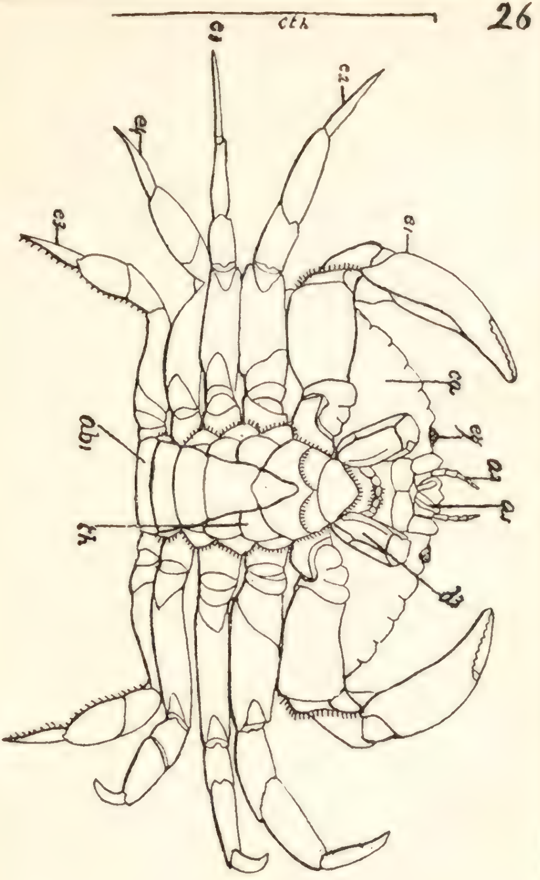


(Fig. 26, *ab* 1–5), is reduced to a mere flap turned under the cephalothorax, while its appendages in the

Fig. 27.

Cancer irroratus (after Morse).

Female carrying eggs under the abdomen, which is for this reason extended behind, like the same part in the lobster.

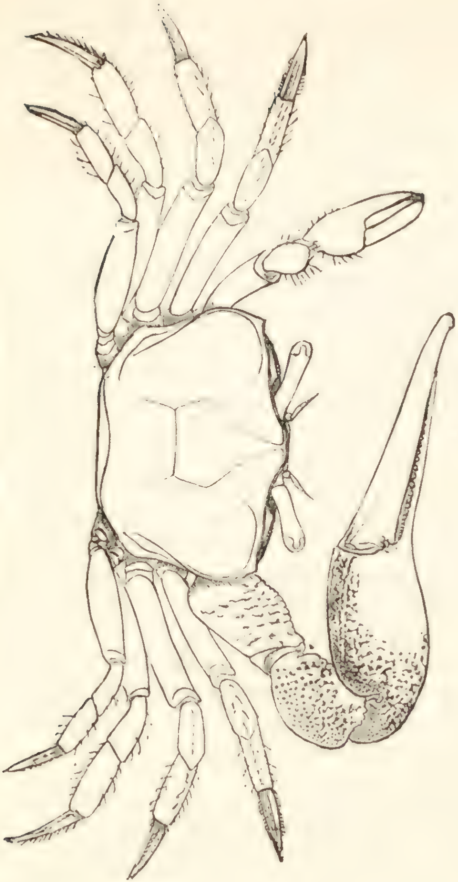
female (Fig. 27) are reduced in size and covered up between the thorax and abdomen, and are used only for holding the eggs.

The abdomen of the male is smaller, more pointed, and the anterior appendages are not so well developed. The cephalothorax (Figs. 25, 26, *cth*) is broader than that of the lobster, but its appendages are equal in number, consisting of five pairs of walking-legs (Figs. 25, 26, *e* 1–*e* 5), six pairs of mouth parts, two pairs of antennæ (Fig. 26, *a* 1, *a* 2), and a pair of eye-stalks (*ey*). The pupils cannot fail to observe, however, that these appendages are crowded more

closely together than those of the other Crustacea they have studied. If they dissect the crab, they find a great concentration of the internal organs, especially of the nervous system. Instead of many ganglia scattered along a nerve-cord, all the ganglia behind the mouth in the crab have coalesced to form a single mass. Thus it is seen that not only are the two regions of the body concentrated in the crab as in the lobster, but the third or abdominal region is doubled up under the cephalothorax, so that, when looked at from above, the crab appears to be merely a perambulatory cephalic shield.

The crab moves sidewise, and when cornered faces the enemy with its two arms thrown up, and ready for action. The jaws are used, not only for capturing, killing, and crushing the prey, but also perform the additional labor of holding it up to the mandibles and helping them to tear off pieces of suitable size for chewing, thus taking the work done in the lobster by both the arms and the third pair of maxillipeds. They are, therefore, not twisted so much as in the lobster, but work vertically, and the arms are not too long, being able to reach the mouth by a sharp bend. The legs of one side are used to push with, and those of the other to pull with, when the crab is in motion. Those of the same side do not, however, all move together, but alternately, so that there is no halting in their gait ; some of the legs are always in the act of taking new steps, and by shoving and pulling in unison a continuous motion is kept up. This crawling by means of jointed appendages can be imitated after having once seen a live crab. Cross the two

Fig. 28.



Gelasimus pugilator (after Emerton).

wrists side by side, placing the fingers down on a level table; bind the wrists by an elastic band, hold them well up from the table, so as to show the fingers. Then let one set crawl while the other pushes, so as to keep up a continuous motion sidewise without assistance from the arms. The terminal sections of the legs show wear only on the points where these are inserted in the ground.

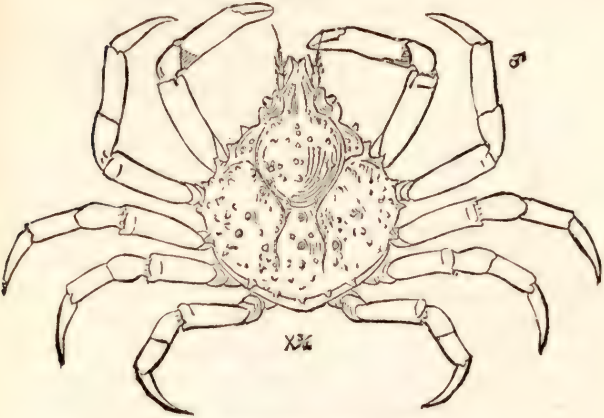
Some of the Brachyura not only walk, but also swim rapidly sidewise with oar-like paddles which are developed from the fifth pair of walking-legs. The blue crab of southern New England, Callinectes hastatus, is a common type of this group.

The Fiddler crab (Fig. 28) is smaller than the common crab, though like it in important structural characters. One of the arms of the male is very much larger than the other, giving a peculiar appearance to the animal, which is supposed to remind one of a violin. The large arm is used in fighting, which accounts for its size and strength. The females have little inclination to battle, and both arms are small. Thus, though the two arms are naturally, or, as we might more strictly say, normally equal, one becomes larger by the more active use it is put to by the male, for the same reason that our right arm becomes larger than our left. Occasionally crabs are found which are left-armed, just as our children are sometimes left-handed.*

* If teachers could but see the true meaning of such facts, and apply them, they would abandon the practice of confirming children in the habit of making themselves one-sided, and would encourage them to use both hands. One of these days this custom of teaching children to use the right arm and right side, to

The Spider crab is a curious form (Fig. 29) which inhabits the shallow waters along the coast, and is frequently found covered with algæ, barnacles, or even

Fig. 29.



Libinia canaliculata (after Emerton).

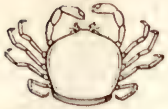
oyster-shells, showing that it does not shed its shell as often as the lobster or most of the Brachyura. The form is intermediate, in respect to the shape of the cara-

the injurious exclusion of the left, will be looked upon as one of the numerous indications of the unenlightened condition of the human mind at the present time. Other indications, such as the barbarous habit of piercing the ears, and the unhealthy practices of wearing corsets and tight boots, are in opposition to the teachings of physiology, as well as those of good taste, and can only be accounted for by the prevailing blindness to their real ugliness and ignorance of the extent of the injuries caused by their use.

pace, between the Macroura and the higher Brachyura, and this coincides also with its sluggish style of walking, long, weak appendages, and generally immature characteristics, as compared with those of the more perfect walking forms of the latter.

That curious little parasite, the Oyster crab (Fig. 30), also belongs among the Brachyura, but can be more appropriately described farther on.

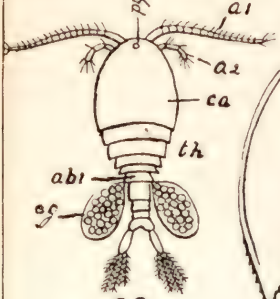
Fig. 30.



Pinnotheres ostreum (after Morse). Female.

In the Brachyura we get the highest expression of the concentration of the regions, and not only this, but a still more remarkable change, since the cephalothorax tends to become broader from side to side. The general concentration seems to be well accounted for by the change of function from a swimming to a walking type, but how shall we account for this lateral spreading? The animal, having a narrow body, could not move with as great rapidity as if it used the legs of one side in pushing and those of the other in pulling the body simultaneously. Any effort to do this would certainly cause a great increase in lateral development, and materially alter the form, so that in its progress sidewise it would offer as little resistance to the surrounding medium as the elongated bodies of animals which habitually move forwards. In other words, the reason why the crab crawls sidewise is, that it is the direction in which its type can move with the greatest readiness and acquire the greatest strength of limb and the maximum of speed.

The history of the development of the Crustacea, in



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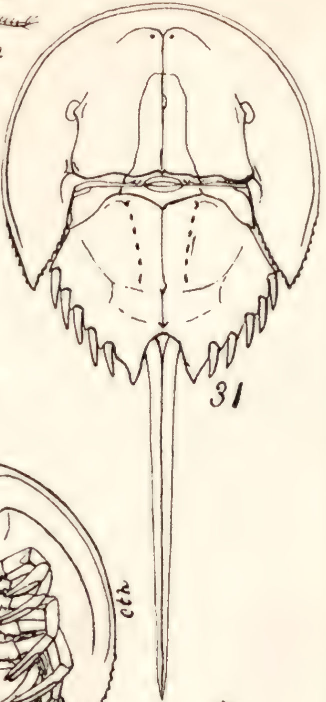

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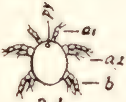

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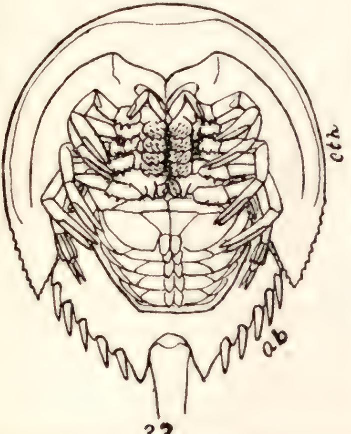

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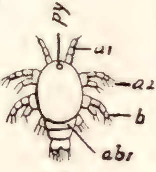

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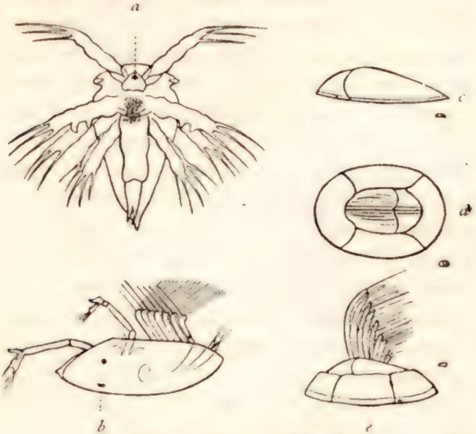
spite of its peculiar interest, must be omitted for want of space. Information on the subject may be obtained from Packard's "Zoölogy," or from almost any of the manuals.*

Fig. 36.



Balanus balanoides (after Morse).

a, Nauplius young; *b*, young about to attach itself; *c*, *d*, young barnacle with shell formed and legs retracted; *e*, same, with legs extended, in the act of fishing. The dots show approximately the natural size of the animal.

We have described the Isopods, Amphipods, and a typical form of the Anomoura, Macroura, and Brachyura, but there still remain unnoticed several very remarkable orders, of which mention is made in all the

* See also "On the Development of Decapod Crustacea." Spence Bate. "Early Stages of the American Lobster." Smith. Trans. Conn. Acad., Vol. II. "Development of Squilla." Brooks. Biological Studies. 1878. Woodward's article on "Crustacea," in the *new* edition of the "Encyclopædia Britannica."

text-books. To the lowest order, Cirripedia, belong the barnacles (Figs. 36, 37,* 38†) which whiten our rocky shores, and the piles of our wharves and bridges between tide-marks, with their innumerable shells. Though formerly classed with the Mollusca, these animals are true Crustacea. Attention is called to them here because they are familiar, and also because they are good illustrations of what is known as retrograde development. The young barnacles are free-swimming (Fig. 36, *a*), but after a time they cement their forward ends to the rocks by a sticky secretion which flows from the antennæ. The outer skin becomes calcified, and forms a conical shell of several pieces (Figs. 37, 38, *v*). In the top of the shell there are two valves, which, in the living animal, open and close. When open, six pairs of many-jointed appendages (Fig. 37, *e* 1–*e* 6) are thrust out. These are beset with hairs, and, sweeping through the water, they catch the food upon which these creatures feed, and carry it to the mouth. Groups of living barnacles may be obtained from the bottoms of vessels, or from piles or rocks, and when placed in sufficiently shallow water may be seen to use their legs in feeding. The articulated or crustacean character of these appendages can be readily seen in all but the smallest species.

As Huxley says, the barnacle is an animal turned upside down, and kicking the food into its mouth with its legs. To us, however, it is an important illustration of the way in which a Crustacean may become adapted to lead a sedentary life, and to get its food by fishing

* Balanus tintinnabulum. † Balanus Hameri.

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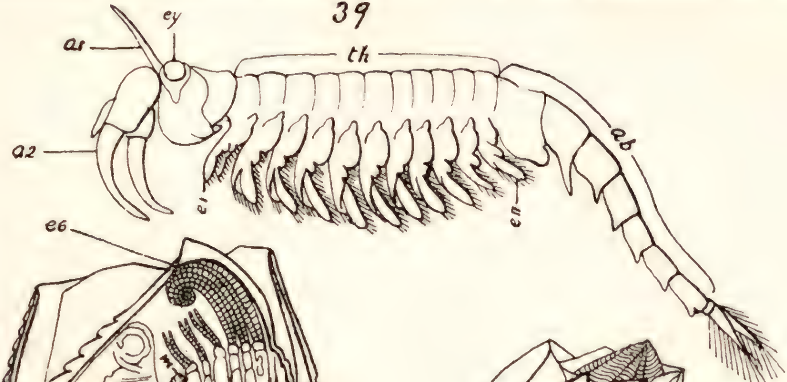

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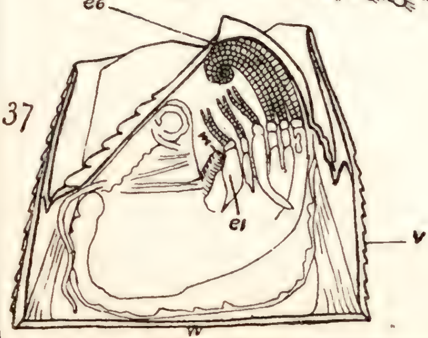

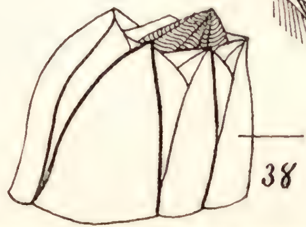

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in the waters, though wholly unable to walk. It must be remarked also how this capacity of a locomotive organism to change has enabled it to occupy places where, but for this capacity, it could not have existed. Thus it can live successfully upon the rocks, and anchor itself securely where the surf would sweep away or destroy the typical forms of the same class. It will be seen, moreover, that the barnacle accomplishes this by changing during its growth from the common Nauplius, or typical Crustacean, to a form which is difficult to recognize as belonging to the same class.

The order Copepoda is represented by the genus Cyclops, found in great numbers in fresh water, and often seen in our drinking water.

The body of Cyclops (Fig. 33) is shaped somewhat like a pear. In the middle of the front of the head there appears to be a single eye (*p y*), though closer observation proves that this eye is really double. The two pairs of antennæ (*a* 1, *a* 2) are the chief organs of locomotion. Following the antennæ come the mandibles and two pairs of maxillæ, and next to these the five pairs of swimming-feet, most of these being invisible from above. The egg-masses attached to the first abdominal ring are very characteristic of the animal (Fig. 33, *eg*). The similar form of the young or Nauplius form in all the Crustacea may be seen by comparing (Fig. 34) the young of Cyclops with (Fig. 36, *a*) that of the barnacle, both of them having the three pairs of appendages (*a* 1, *a* 2, and *b*). Fig. 35 represents an older stage, during which the abdominal segments make their appearance. See also the young of Lernea branchialis (Fig. 40).

Closely allied to the Copepoda are the Epizoa, or "fish-lice." This division of parasites contains a great number of forms, which have been so entirely changed, and often so degraded in structure, that it would not be possible to recognize them as belonging to the class if it were not, as in the barnacles, that the young are in their early stages of development true Crustaceans (Fig. 40). They are parasitic, living on or in other animals, and specimens of some of them may be found on fishes, attached to the gills, or hanging from the skin just behind the fins, with the forward part of their bodies deeply buried in the flesh. Having no need of eyes, appendages, or of stomachs, as they take their food directly by suction, or through the skin of the body by absorption, they lose most of these organs, or all of the more important ones, and become in some cases mere sacks without shells or jointed appendages, having no likeness to any normal articulated Crustacean. Lernea branchialis (Fig. 40) is one of the most degraded forms of this order, and is not uncommon on the gills of codfishes. Its body is not segmented, and ends in two long egg-masses. It is destitute of locomotive appendages and sense-organs. The parts around the mouth are modified into root-like appendages, and these are buried in the flesh of the animal upon which this parasite feeds.

The curious extent to which parasitic habits may alter the organization can be studied in the very familiar animal, the little Oyster crab (Fig. 30, p. 62), which can be obtained from oyster-openers by the hundred, if wanted. In this case a Decapod, or true hard-shelled crab, living inside of the oyster and brows-

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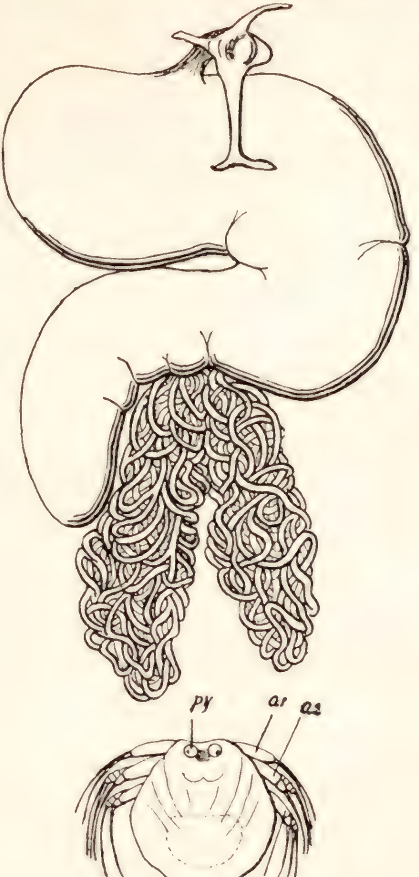

ing on the food accumulated by the surfaces of the gills, loses its power to make a hard, thick shell, and becomes an albino, being colorless. The terminal sections of the legs are hooked, and used to hold on with instead of for walking, and the arms are short and weak, as is suitable to their style of feeding. It does not seem to injure the oyster materially, though it sometimes causes a slight distortion of the gills. It is not a true parasite, feeding on the blood or juices of the oyster, but a sort of companion, a commensal parasite. The males are generally free and very rare, and females alone are found with the oysters.

The genus Branchipus (Fig. 39), belonging to the Branchiopoda, is found in great numbers in rain-pools and fresh-water ditches in the early spring. It is a very curious animal, and interesting to children on account of its habit of swimming with its back downward, and the oar-like appendages with which it moves along.

Specimens of the order Ostracoda are found frequently in our fresh-water ponds, but these are too small to be studied by the unaided eye. They closely resemble small bivalve shells, the similarity being due to the shape of the carapace, which also sometimes has lines of growth like those of shells.*

It only remains for us to compare the two great classes, Worms and Crustacea. In the higher worms, such as we have used to illustrate the group of Vermes, we find an elongated body, the two ends of which are often similar in form, though distinct in function.

* Excellent figures and descriptions of these can be found in Morse's book, already cited.

The consolidation of a few of the anterior rings has produced in many genera a cephalic or mouth region. The skin of the segmented body is covered with a chitinous cuticle, and bears either setæ, or unjointed appendages, or both. Respiration is effected by the general surface of the body, and by the appendages, and no heart comparable with that of the Crustacea is present. Adult size is attained by the development of rings between those already formed near the posterior end of the body, i.e. between terminal and subterminal rings.

In the Crustacean, on the other hand, the number of segments is less variable and the full complement is attained in the early stages of growth. The body is shortened, and the two ends are not only distinct in function, but very different in form. A coalescence of a number of the anterior rings has produced a complicated cephalic or mouth region, and in the higher forms a cephalothoracic region. The segmented body in most forms is covered with a hard crust or shell, and bears jointed appendages. Respiration is usually carried on by gills, a heart is generally present, and growth is made possible by repeated moults of the unyielding shell.

Figs. 31 and 32 are views of the horse-shoe crab [Limulus], viewed from the upper and under sides, showing the three regions of the body and the mouth between the bases of the walking legs. This animal is not properly a Crustacean, but the figures of it have been given here because it is referred to in many textbooks as a Crustacean. The structure will be noticed in the Guide which treats of Millepods, Scorpions, and Spiders.

Typography by J. S. Cushing & Co., Boston, U.S.A.